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INVESTIGATIONS ON THE PHYTOPLANKTON IN THE DANISH WADDENSEA IN JULY 1941

BY

JUL. GRØNTVED

WITH THIRTY-EIGHT TEXTFIGURES AND TWO PLATES

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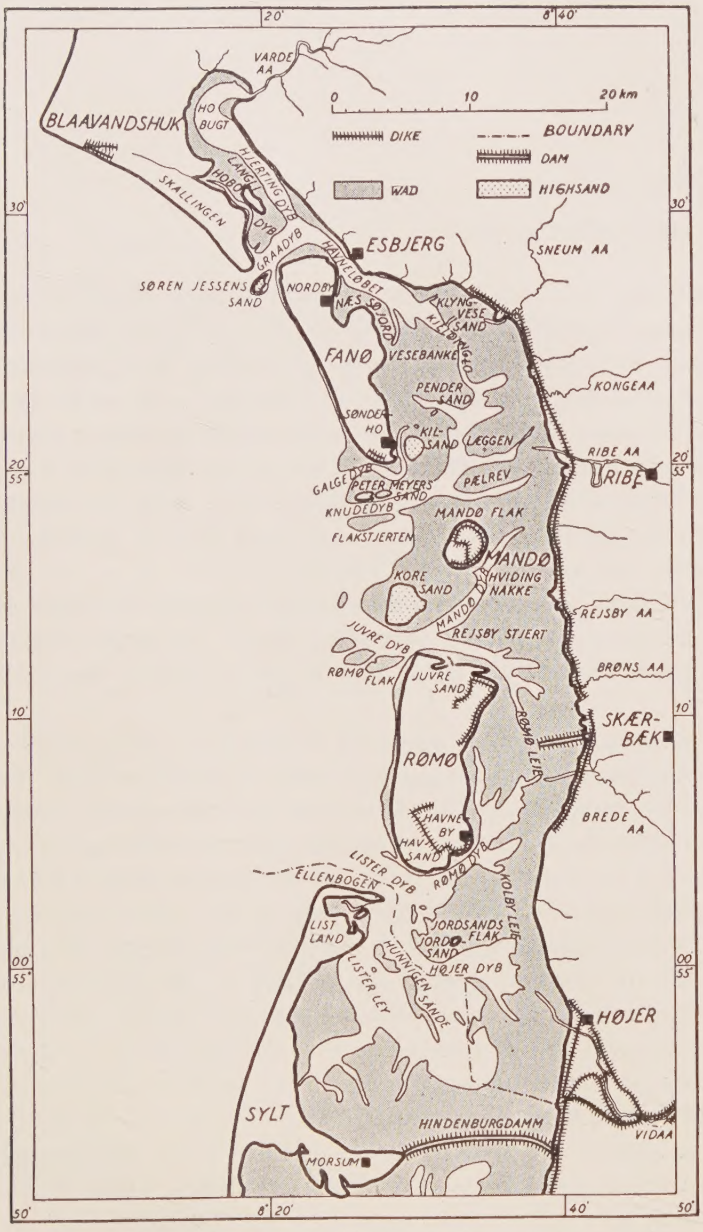

Fig. 1. Map of the Danish Waddensea (from A. LUNDBAK).

half of July 1941; this plankton collection was part of a scientific investigation embracing moreover the hydrography of the area concerned, mud content of the water, stock of higher plants on the wads etc., and was set on foot at the instigation of "Vadehavsudvalget af 1941", which was considering the possibility of reclaiming land in the area. As a member of this committee Professor NIELS NIELSEN arranged for the various collections and observations carried out in 1941.

As the collections were only made over a short period, the yearly fluctuation of the plankton stock cannot be discussed; but the plankton stations lie so close together, that the material yields a good picture of the momentary stock during the collecting period; further, the samples were taken at such short intervals at the various stations, that the fluctuation of the plankton during the ebb and flow of the tide can be followed fairly closely.

In bringing this work to a conclusion my best thanks are here given to Professor NIELS NIELSEN, who gave me the opportunity of participating in the work in 1941; I had not seen the marshes and Waddensea before then and my daily work there gave me a deep impression of the special character of those waters. Cand. mag. ASGER LUNDBAK, who — with civil engineer J. VICKENS — was concerned with the hydrographical observations, has loaned me his manuscript to make use of in drawing up the present report; I wish to extend to him my sincere thanks.

II. Material and Methods.

The part of the Danish Waddensea where investigations were undertaken in 1941 is divided by higher wad areas at Mandø ebb-path and Rømø Leje into three tidal areas, one

within each of the three large Deeps: Knudedyb, Juvre Dyb and Lister Dyb.

The plankton stations, as shown in Fig. 2, are distributed over the three areas; stations 1—4, 3b and E lie in the Lister Dyb area, St. B on the border between this and the Juvre Dyb area where stations 5, 5a, 6 and 7 lie; St. 8 is the only plankton station in the tidal waters of Knudedyb; with single exceptions (St.4, St. B) all the stations are located in the Deeps and runlets that cut into the Waddensea from the west. Regarding the position and depth of the various stations the following information may be given.

St. 1 lies in the inner, broader part of Højer Dyb; depth 1 m.[1]).

St. 2 lies farther out in Højer Dyb, off the southernmost point of Jordsands flat. Depth 14 m.

St. 3 lies in Rømø Dyb near the place where Rude Dyb forms a branch inwards into the Waddensea; depth 14 m. ($^{14}/_{7}$, 10 m.).

St. 3 b lies farther in Rømø Dyb, off Havneby on Rømø; depth 10.5 m.

St. 4 lies in the shallow area Kolby Leje inside Rude Dyb and at some distance from Højer Dyb; depth .25—.50 m.

St. E lies farthest inside one of the northern blind alleys of Rømø Dyb; depth .25 m.

St. B is in Rømø Leje between Lister Dyb and Juvre Dyb tidal areas. The station is situated in the direction of the then unfinished Rømø dam a short distance west of the place to which the dam had then reached; depth at high tide 1.16 m.

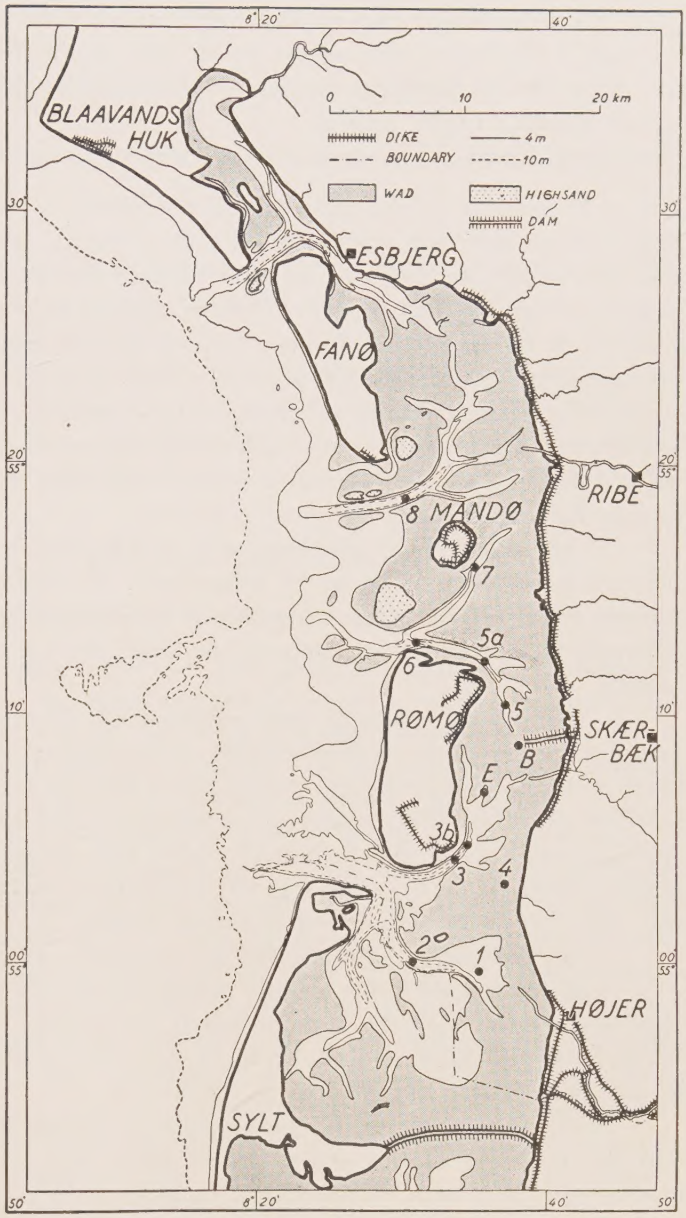

Fig. 2. Map showing the position of the plankton stations in July 1941.

St. 5 lies in the northern part of Rømø Leje in the southern branch of Juvre Dyb; depth 2.25 m.

St. 5a is likewise situated in the southern branch of Juvre Dyb, almost midway between the stations 5 and 6 off the north-east point of Rømø; depth 7 m.

[1]) The depths refer to the condition at lowwater.

St. 6 lies in the outer part of Juvre Dyb in the area where the Deep branches into a northern and a southern part, on the south side of the Deep; depth 16.5 m. ($^{28}/_{7}$, 14 m.).

St. 7 lies in the northern branch of Juvre Dyb: Mandø Dyb, due east of the south point of Mandø; depth 3.25 m.

St. 8 lies in Knudedyb a short distance west of the place where the Deep branches; depth 14 m.

At stations 1—8 synchronised collections of plankton were made on 14, 15 and 28, July, but no plankton was collected at St. 1 on 14, and 15, July, nor at St. 2 on 14, July. The aim was to get the series of samples at each station to cover a whole tidal period, beginning with the morning highwater. We were obliged to make this the starting point for practical reasons, as the depth conditions at Ballum sluice, where the observation boats had their base, only permitted sailing during highwater, and as sailing under the then existing war conditions could only be undertaken in daylight. It is probable that the plankton would have varied in a more regular manner if the collections had embraced tidal periods from lowwater to low-water, since we should then have had to deal with the same water-masses to a greater extent, during the ingoing and outgoing currents.

The collection of plankton was coordinated with hydrographical observations, so that the two series were taken at the same time. The plankton samples were taken at intervals of 2 hours (near the equal hour numbers); in addition, to make the series as complete as possible, a sample was taken immediately on the boat's arrival at the station and one immediately before sailing.

The sample material comes exclusively from the surface; it consists partly of water-samples, partly of a smaller number of filtered samples; at all stations water-samples were taken every second hour. They were taken directly with the sample bottle; at the stations 2—6, together with this 50 cc. sample an other was taken with a 2 litre can; this was filtered on the spot through a sieve, the bottom of which was covered with silk gauze No. 25 (the side of its meshes being ca. 50 μ); what was left on the filter was transferred to a sample glass tube, which was filled up with water to a standard height.

The preserving solution for all samples was neutral formaline.

To investigate some details which could not be expected to show themselves in the sample material from the stations noted, collections were made in the area inside Rømø, on $^{17}/_{7}$ at St. B and St. E and on $^{20}/_{7}$ at St. 3b and 5a; water samples were taken at all these and in addition filtered samples at St. 3b and E.

For microscopic examination sediment preparations were made from the water samples and the counting of the organisms in these was made by means of UTERMÖHL's reversed microscope; the material examined quantitatively consists of 181 water samples, from

St. No.	No. of samples	St. No.	No. of samples
1	8	7	24
2	12	8	22
3	22	B	5
4	23	E	6
5	23	3b	7
6	22	5a	7

The filtered samples have not been examined quantitatively; this series forms a supplement to the water samples, rendering it possible to determine the presence of larger forms, which are so feebly represented in the water masses, that there is but little probability that

they could be observed in the water samples. The series consists of 115 filtered samples collected at the following stations:

St. No.	No. of samples	St. No.	No. of samples
2	12	6	22
3	22	E	6
4	23	3b	7
5	23		

In the shallow water area with soft bottom at several places the bottom material is readily brought into suspension by movements in the water, and the water thus becomes unclear or even more or less cloudy; this condition is due partly to inorganic matter, partly to remains of plants and matter of animal origin. The microscopic examination of the plankton in such unclean water has been very laborious; in most cases it was found necessary to dilute the portion of the samples examined, so that the organisms in the sediment preparations should not be covered by detritus to such an extent as to introduce a serious error in the countings.

III. Investigations at the various plankton stations.

1. Synchronised investigations 14, 15, and 28, July 1941.

Figs. 3—23 give the number of diatoms in the tidal periods considered, represented by two curves. The continuous line shows the total number of diatoms, whilst the dotted line indicates the proportion of bottom diatoms in the total; the distance between the two curves thus gives the number of plankton diatoms. It should be emphasised, however, that the boundary between the two biological groups of diatoms is by no means sharply defined.

The results of the counts have not been published *in extenso*. Table 25 shows the average number of specimens of all observed species in all the samples. From this, however, we cannot ascertain how far the numbers for the various species vary with the tidal movements and this cannot be determined either from Figs. 3—23; however, a majority of the species have so small a concentration, that the frequency numbers do not show with any certainty their dependence on tidal movements; the occurrence of these species may be considered as sufficiently illustrated by the averages in Table 25. A smaller number of species occur in such abundance, that their quantitative variation with the changing of the tidal phases is determined fairly exactly; their concentration in the various samples can be seen from Tables 1—21. It is indeed of importance to have determined the fluctuation of the dominant species at the various stations, since in this way we obtain information that — together with the averages (Fig. 37) — renders it possible to throw light on the distribution of the diatoms in the area investigated.

Figs. 3—23 show graphically the direction and strength of the water-movements at the surface (ingoing current above, outgoing current below the 0-line); in this way the different phases of the tidal periods can be seen along with the fluctuation of the diatoms. The salinity of the water at the surface and bottom is likewise added in Figs. 3—23.

As to the temperature the daily variations are greater at the inner stations than at the outer ones; the extreme values are given here:

Date	Sts. 1, 4, 5 and 7	Sts. 2, 3, 6 and 8
$^{14}/_{7}$	18.1°—24.8°	21.7°—25.2°
$^{14}/_{7}$	18.0°—24.3°	21.2°—23.5°
$^{28}/_{7}$	19 5°—23.3°	19.5°—20 7°

a. St. 1, Højer Dyb.

(Table 1; Fig. 3).

No plankton collections were made at St. 1 on 14, and 15, July; the material examined embraces 8 plankton samples from $^{28}/_{7}$.

The average number of diatoms amounts to 130,000 specimens per litre, the bottom diatoms contributing 22,000. There is a fairly close relationship between the plankton at this

The concentration (cells per litre) of the most common diatom species at St. 1, Højer Dyb.

Table 1. — $^{28}/_{7}$ 41.

Hour	6^{00}	8^{00}	10^{00}	12^{00}	14^{00}	16^{00}	18^{00}	20^{00}
Asterionella japonica	10,000	19,000	8,000	3,000	..	45,000	43,000	10,000
Biddulphia aurita	2,000	3,000	..	2,000	2,000	2,000	1,000	..
— rhombus	2,000	2,000	2,000	5,000	7,000	11,000	..	..
Campylosira cymbelliformis	3,000	3,000	..	..	..	..	3,000	..
Guinardia flaccida	2,000	11,000	..	..	..	..	4,000	3,000
Melosira sulcata	6,000	12,000	..	..	..	4,000	5,000	..
Nitzschia closterium	1,000	2,000	2,000	1,000	1,000	1,000	5,000	..
Rhizosolenia Shrubsolei	122,000	82,000	23,000	4,000	3,000	55,000	101,000	93,000
Sceletonema costatum	16,000	12,000	15,000	..	3,000	19,000	8,000	12,000

The concentration (cells per litre) of the most common diatom species at St. 2, Jordsand.

Table 2. — $^{15}/_{7}$ 41.

Hour	9^{15}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	19^{10}
Asterionella japonica	196,000	118,000	10,000	24,000	154,000	196,000	290,000
Biddulphia aurita	2,000	6,000	2,000	1,200	1,000	200	3,000
— rhombus	2,000	2,000	6,000	6,000	4,000	200	..
Campylosira cymbelliformis	..	4,000	..	..	..	..	..
Lithodesmium undulatum	6,000	..	14,000	2,800	1,000	17,200	..
Melosira sulcata	..	14,000	..	3,600	..	..	..
Nitzschia closterium	2,000	..	1,000	2,000	6,000	4,000	2,000
Rhizosolenia Shrubsolei	10,000	24,000	4,000	2,000	5,000	4,000	7,000
Sceletonema costatum	80,000	32,000	26,000	42,000	31,000	18,000	55,000

Table 3. — $^{28}/_{7}$ 41.

Hour	8^{15}	10^{15}	12^{15}	14^{15}	18^{15}
Asterionella japonica	30,000	10,000	54,000	29,000	14,000
Biddulphia aurita	3,000	..	..	2,000	1,000
— rhombus	..	4,000	4,000	2,000	..
Campylosira cymbelliformis	4,000	4,000	..	3,000	5,000
Guinardia flaccida	9,000	4,000	4,000	4,000	11,000
Melosira sulcata	5,000	..	..	..	16,000
Nitzschia closterium	1,000	3,000	2,000	1,000	2,000
Rhizosolenia Shrubsolei	111,000	109,000	34,000	90,000	188,000
Scleletonema costatum	..	20,000	9,000	19,000	..

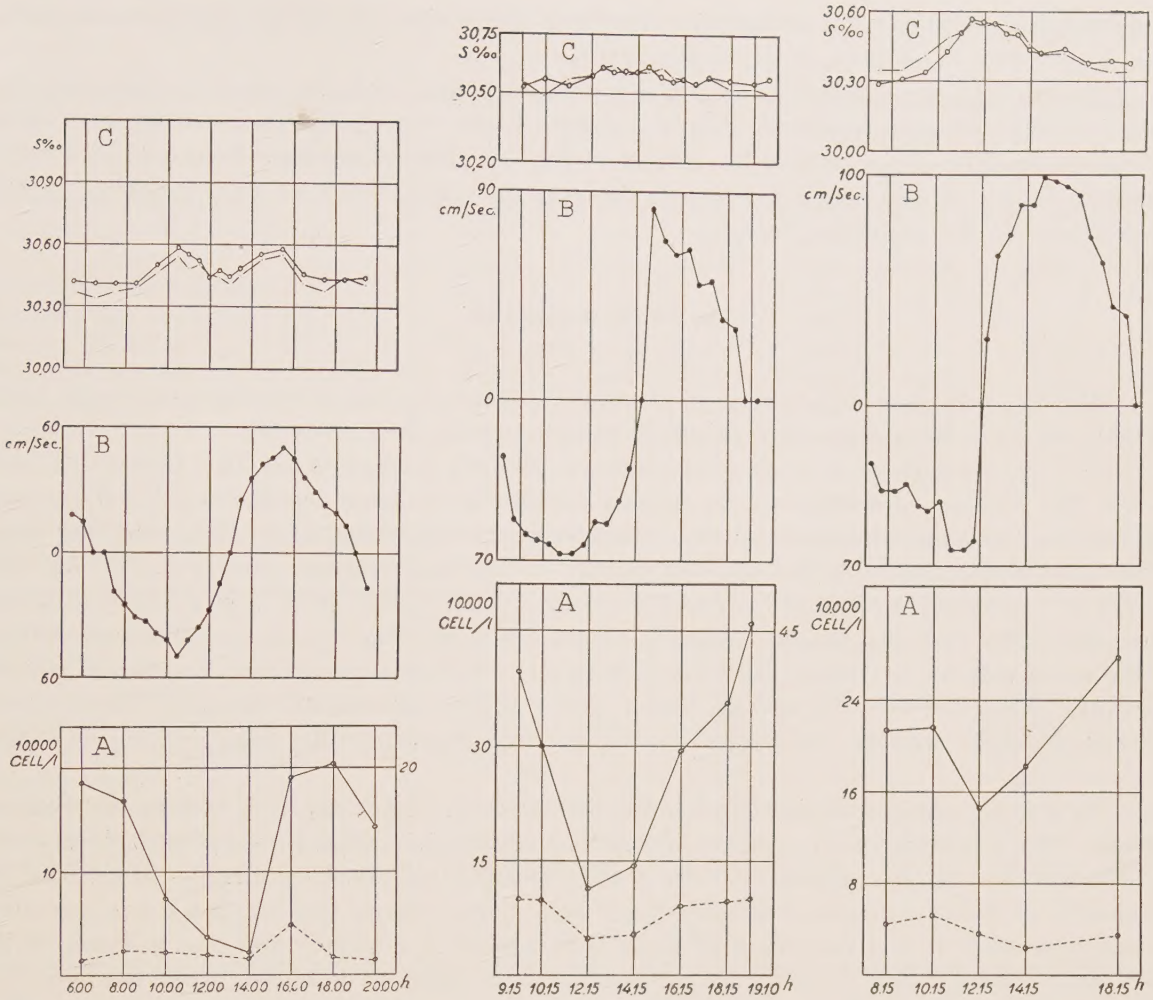

Fig. 3. Fig. 4. Fig. 5.

Fig. 3. St. 1, Højer Dyb, $^{28}/_{7}$ 41. Fig. 4. St. 2, Jordsand, $^{15}/_{7}$ 41. Fig. 5. St. 2, $^{28}/_{7}$ 41. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o---o---o bottom diatoms. *B*: Current measurements at the surface. *C*: Salinity. o—o—o surface, •—•—• bottom.

station and St. 2 lying farther out in Højer Dyb; the dominant species at both places are *Asterionella japonica* and *Rhizosolenia Shrubsolei*; these have a considerably greater frequency at St. 2 than at St. 1 and their fluctuation shows the greatest range at St. 1, chiefly on account of the small numbers in the lowwater samples. This applies also to a number of less frequent species: *Campylosira cymbelliformis*, *Guinardia flaccida* and *Melosira sulcata*, whilst *Sceletonema costatum*, which is almost equally frequent at the different phases of the tidal period at St. 1, only occurs in the lowwater samples at St. 2; when the tides are halfway this species has its greatest density in the water-masses round St. 1, whereas the other forms mentioned have the greatest concentration outside St. 2.

At St. 1 few specimens were found of the green alga *Scenodesmus quadricauda*, which presumably is carried out into the Waddensea by water from the Vidaa River; in the area investigated it is only known from this one station. In Ho Bay, on the other hand, it shows

greater frequency at the outlet of the River Varde aa along with other freshwater forms, forming there a very rich local flora (GRØNTVED, 1940).

The salinity curve with its two partial maxima about ebb-tide change shows that the water-masses in an area inside St. 1 have a slightly higher percentage than outside; farther in the percentage falls again, as can be seen from the lowwater minimum. The small variations in salinity occurring here and elsewhere in the area have apparently no great influence on the development of the plankton flora.

b. St. 2, Jordsand.

(Tables 2—3; Figs. 4—5).

On 14, July weather conditions prevented collections and observations at St. 2; from July 15, we have the results of 7 plankton samples and 5 from July 28.

For $^{15}/_{7}$ the average number of diatoms was 296,000 specimens per litre, bottom diatoms 83,000. The number of diatoms in the various samples shows great fluctuations, the frequency numbers for the most abundant species *Asterionella japonica* rising and falling with the state of the tide; consequently, it has greatest density in the water-masses outside St. 2. That the species on $^{15}/_{7}$ shows a relatively smaller frequency at St. 2 than at St. 3 is possibly to some extent due to the fact, that the boat making collections at St. 2 lay on that day (but not on $^{28}/_{7}$) on the north side of the Deep near Jordsands shoal; under these conditions we should expect a weaker concentration of a species which shows increasing density outwards. *Sceletonema costatum* is fairly frequent, but shows no characteristic relation to the tidal rhythm, as is the case on $^{28}/_{7}$.

On $^{28}/_{7}$ the average number of diatoms is 207,000 specimens per litre, with 39,000 bottom diatoms. The dominant species is now *Rhizosolenia Shrubsolei*, which shows greatest frequency at highwater, but is also abundant at the change of ebb; this plankton form — in contrast to *Asterionella* — shows a greater density in Højer Dyb than in Rømø Dyb; in fact it has a greater average frequency at St. 1 innermost in Højer Dyb than at St. 3 in the outer part of Rømø Dyb. *Asterionella japonica* and *Sceletonema costatum* show a different variation from that on $^{15}/_{7}$, being relatively more abundant in the lowwater samples; as both species are greatly on the decline during the period of investigation, the indications are that the stock under such conditions can maintain itself longer in the inner parts of the Waddensea than in the outer; that this should be due to the fact, that the salinity is inconsiderably greater inside St. 2 than outside, is not probable. According to LUNDBAK this condition arose from the fact, that in the days before $^{28}/_{7}$ the evaporation in the area inside St. 2 exceeded the freshwater addition; thus, just an occasional phenomenon.

c. St. 3, Rømø Dyb.

(Tables 4—6; Figs. 6—8).

At this station 7 plankton samples were taken on each of the days 14, and 15, July; on $^{28}/_{7}$ 8 samples were taken.

St. 3 is the richest in plankton within the area, though the number of specimens for St. 6 on $^{28}/_{7}$ is slightly larger. The average numbers of diatoms — in chronological order for the three days — were 1,382,000, 994,000 and 245,000 specimens per litre, the bottom diatoms respectively 183,000, 171,000 and 44,000. *Asterionella japonica* is the most abundant; it is

The concentration (cells per litre) of the most common diatom species at St. 3, Rømø Dyb.

Table 4. — $^{14}/_{7}$ 41.

Hour	9^{00}	9^{50}	12^{18}	14^{15}	16^{15}	18^{15}	20^{15}
Asterionella japonica	1,314,000	1,488,000	868,000	328,000	433,000	1,080,000	1,610,000
Biddulphia aurita	18,000	4,000	6,000	2,000	2,000	1,600	2,000
— rhombus	22,000	12,000	28,000	12,400	11,000	4,000	2,000
Campylosira cymbelliformis	..	..	..	4,000	13,000	..	22,000
Lithodesmium undulatum	6,000	8,000	2,000	4,000	..	..	..
Melosira sulcata	14,000	..	..	2,400	..	2,600	..
Nitzschia closterium	48,000	18,000	52,000	8,800	9,000	2,400	16,000
Rhizosolenia Shrubsolei	2,000	4,000	..	800	4,000	9,800	4,000
Sceletonema costatum	246,000	92,000	98,000	154,000	62,000	62,000	88,000

Table 5. — $^{15}/_{2}$ 41.

Hour	10^{17}	12^{15}	14^{15}	16^{15}	18^{15}	20^{15}	21^{03}
Asterionella japonica	892,000	460,000	276,000	458,000	645,000	794,000	905,000
Biddulphia aurita	14,000	12,000	7,000	14,000	..	1,000	1,000
— rhombus	10,000	56,000	28,000	4,000	4,000	2,000	2,000
Campylosira cymbelliformis	16,000	6,000	4,000	..	..	10,000	..
Lithodesmium undulatum	2,000	8,000	10,000	..	..	8,000	..
Melosira sulcata	..	10,000	6,000	..	..	3,000	..
Nitzschia closterium	18,000	20,000	24,000	32,000	8,000	5,000	4,000
Rhizosolenia Shrubsolei	6,000	8,000	..	..	2,000	4,000	12,000
Sceletonema costatum	142,000	238,000	126,000	200,000	72,000	33,000	36,000

Table 6. — $^{28}/_{7}$ 41.

Hour	6^{19}	8^{15}	10^{15}	12^{15}	14^{15}	16^{15}	18^{20}	19^{40}
Asterionella japonica	115,000	68,000	56,000	..	23,000	80,000	95,000	118,000
Biddulphia aurita	2,000	4,000	3,000	3,000	2,000	6,000	3,000	2,000
— rhombus	2,000	5,000	9,000	18,000	9,000	3,000	2,000	..
Campylosira cymbelliformis	..	3,000	10,000	..	5,000	..	5,000	11,000
Guinardia flaccida	10,000	10,000	3,000	..	3,000	5,000	12,000	8,000
Melosira sulcata	..	..	3,000	2,000	5,000	..	3,000	6,000
Nitzschia closterium	9,000	7,000	2,000	1,000	6,000	4,000	3,000	2,000
Rhizosolenia Shrubsolei	74,000	59,000	23,000	3,000	26,000	72,000	78,000	53,000
Sceletonema costatum	56,000	43,000	49,000	38,000	84,000	44,000	35,000	41,000

most frequent at highwater, but — especially on $^{14}/_{7}$ and $^{15}/_{7}$ — its great density in the lowwater samples shows, that its area of distribution during this period extends far into Rømø Dyb; the average frequency of the species on 14, and 15, July was 1,017,000 and 632,000 specimens respectively. The cause of this considerable difference in the density on two successive days was partly, that the wind on $^{14}/_{7}$ came from the west and thus favoured the transport of water to the Waddensea, whereas on $^{15}/_{7}$ an easterly wind held up the incoming current. If the species

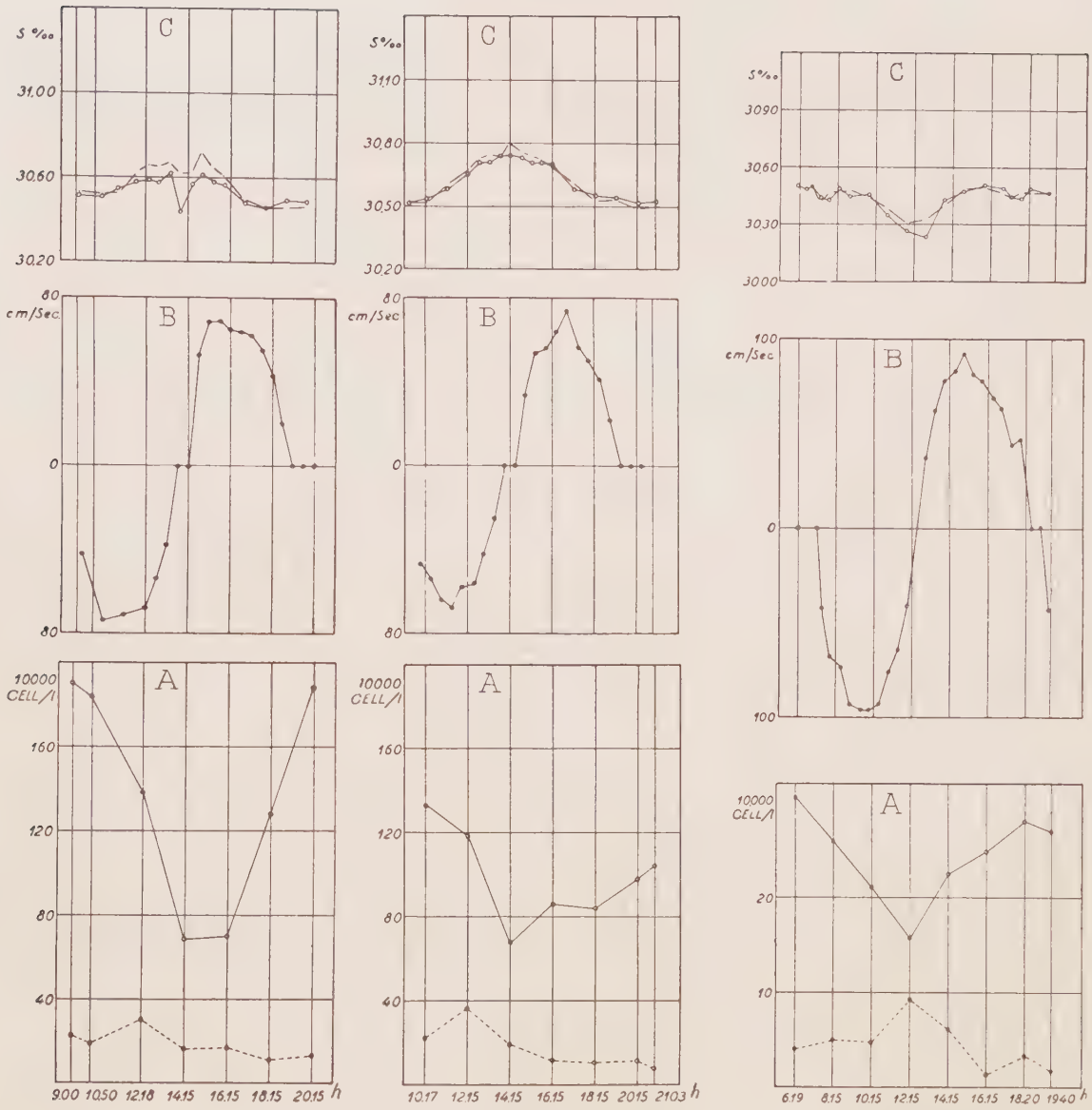

Fig. 6. Fig. 7. Fig. 8.

Figs. 6—8. St. 3, Rømø Dyb. Fig. 6 — $^{14}/_{7}$; fig. 7 — $^{15}/_{7}$; fig. 8 — $^{28}/_{7}$. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o--o--o bottom diatoms. *B*: Current measurements at the surface. *C*: Salinity. o—o—o surface, •—•—• bottom.

has its greatest density outside St. 3, such changes of the weather will produce changes in the concentration like that mentioned. For the rest, the maximum for *Asterionella* was on the decrease during the period (cf. p. 29), and also for that reasen we should expect a lower frequency on the 15, than on the 14, July.

Sceletonema is likewise frequent at St. 3, but with much smaller numbers than *Asterionella* on 14 and 15, July; at the end of July on the other hand the difference is slight; the quantitative variation of this species during the three tidal periods seems to be a matter of chance; this with the fact, that the frequency is much smaller at St. 4 than at St. 3, indicates that the main

distribution of the species lies round Rømø Dyb; that the frequencies on 14, and 15, July are almost the same, also points in the same direction. Occurrences similar to that of *Sceletonema* are shown by the littoral species *Biddulphia aurita* and *B. rhombus*.

On $^{28}/_{7}$ *Rhizosolenia Shrubsolei* shows considerable density varying in the usual manner of genuine plankton forms, with increase during incoming current and decrease under outgoing; *Guinardia flaccida* is like *Rhizosolenia*. That the curve for the total number of diatoms shows the same tendency on this day, is due to the preponderance of neritic plankton forms.

As to the bottom diatoms, their number is greatest during the period of outgoing current; this shows that the stock of bottom diatoms in the water-masses is renewed from the inner parts of the Waddensea. On $^{15}/_{7}$ certainly the total amount of diatoms is largest during the outgoing current, but this comes partly from the large numbers of *Sceletonema*, which like the bottom diatoms can thrive in the inner parts of the Waddensea, and partly from the bottom diatoms being included in the total amount. These conditions may clearly give rise to a skewness in the diatom curve, as the dominant plankton form *Asterionella* was but weakly represented on this day.

When the bottom diatoms and other species, *e. g. Biddulphia aurita* and *B. rhombus*, which depend greatly on the nearness of the bottom, are so abundant in the surface samples in this relatively deep area, this indicates that the microflora is well developed in the lowwater surroundings of Rømø Dyb; in the Deep itself, on the other hand, it is not probable that denser populations of diatoms occur at the bottom.

d. St. 4, Kolby Leje.

(Tables 7—9; Figs. 9—11).

The material contains 23 samples, 7 from $^{15}/_{7}$ and 8 from each of the other days.

The average number of diatoms of 14, 15, and 28, July was respectively 344,000, 283,000 and 54,000 specimens per litre, the bottom diatoms contributing 159,000, 136,000 and 31,000 specimens.

On $^{14}/_{7}$ and $^{15}/_{7}$ the most abundant plankton form was *Asterionella*, which shows distinct fluctuation with greatest frequency at highwater, whilst it has lower density or is quite absent in the lowwater samples; fairly numerous is *Sceletonema*, which varies in quantity like *Asterionella*, but with a smaller variation, in correspondence with the fact, that the main area of distribution for *Asterionella* in the Waddensea lies outside that of *Sceletonema* and for both outside Kolby Leje.

The salinity curves for the two days show 3 pronounced minima, which are considered by Lundbak to come from one and the same body of water, formed at the mouth of the Vidaa River and carried northward with increasing mixture of salt water. Under these conditions we should expect to meet with freshwater plankton forms in the samples taken in or near this body of water, if there is a fairly large freshwater flora at the mouth of the Vidaa River; but the samples do not contain any freshwater forms. On the $^{14}/_{7}$ certainly there were weak traces, consisting of some few empty frustules of *Melosira italica*, but these were found in the sample taken at 16^{15} hours, thus after the minimum had passed St. 4 and there is therefore nothing special to show that their true home is the Vidaa River. There is no doubt, however, that the *Melosira* frustules are carried out into the Waddensea at one of the freshwater outlets which opens into the tidal water area of Lister Dyb, as they have only been found at the stations 2, 3 and 5 in addition to station 4. These resistant silicate frustules are easily borne by the general

The concentration (cells per litre) of the most common diatom species at St. 4, Kolby Leje.

Table 7. — $^{14}/_{7}$ 41.

Hour	7^{15}	8^{15}	10^{15}	12^{00}	14^{15}	16^{15}	18^{15}	20^{20}
Asterionella japonica	140,000	150,000	64,000	..	..	48,000	212,000	182,000
Biddulphia aurita	2,000	2,000	..	4,000	4,000	2,000	2,000	4,000
— rhombus	4,000	4,000	4,000	16,000	6,000	8,000	4,000	4,000
Lithodesmium undulatum	18,000	..	..	..	12,000	..	..	..
Melosira sulcata	4,000	..	..	..	4,000	16,000	..	..
Nitzschia closterium	12,000	14,000	12,000	8,000	14,000	12,000	10,000	12,000
Sceletonema costatum	58,000	50,000	134,000	50,000	12,000	8,000	44,000	74,000

Table 8. — $^{15}/_{7}$ 41.

Hour	8^{15}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	20^{05}
Asterionella japonica	118,000	..	..	20,000	18,000	138,000	200,000
Biddulphia aurita	..	..	2,000	..	2,000	2,000	4,000
— rhombus	4,000	..	6,000	..	..	10,000	2,000
Lithodesmium undulatum	6,000	..	4,000	4,000	2,000	..	..
Melosira sulcata	..	..	..	..	..	8,000	..
Nitzschia closterium	20,000	..	4,000	8,000	4,000	16,000	6,000
Sceletonema costatum	58,000	44,000	18,000	18,000	42,000	72,000	126,000

Table 9. — $^{28}/_{7}$ 41.

Hour	6^{15}	8^{15}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	19^{35}
Asterionella japonica	1,000	..	..	..	..	..	12,000	..
Biddulphia aurita	..	1,000	..	3,000	..	1,000	..	..
— rhombus	..	..	1,000	7,000	8,000	2,000	2,000	1,000
Guinardia flaccida	3,000	..	..	..	..	..	..	..
Lithodesmium undulatum	..	..	..	..	1,000	..	..	..
Melosira sulcata	..	..	6,000	..	..	..	2,000	..
Nitzschia closterium	1,000	..	..	2,000	1,000	..	..	1,000
Rhizosolenia Shrubsolei	25,000	14,000	3,000	..	1,000	19,000	19,000	20,000
Sceletonema costatum	6,000	..	..	..	..	6,000	6,000	6,000

mixing of the waters to any part of the Lister Dyb area, whether they come from the Vidaa River, Bredeaa River or one of the smaller outlets in this section. At St. 5 in the Juvre Dyb area their presence is apparently connected with the north-going current found here at high-water. If we are unable from the very few records to determine exactly the real home of the species in this area, yet they allow us to assume, that the species does not have such an abundant population here at any of the freshwater outlets, as was found at the mouth of the River Vardeaa in August 1938 (Grøntved, 1940, p. 42).

Merismopedia spp. is of considerable abundance at the stations 2 and 4; apparently there is a local centre of distribution between these stations; just at Jordsands shoal near the

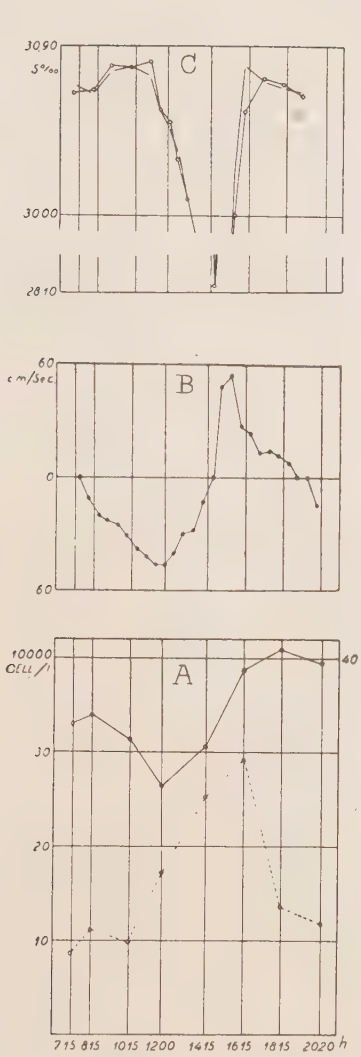

Fig. 9.

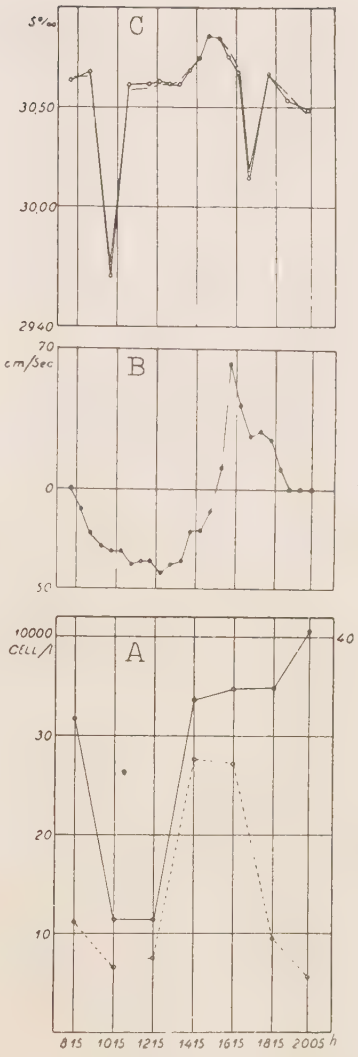

Fig. 10.

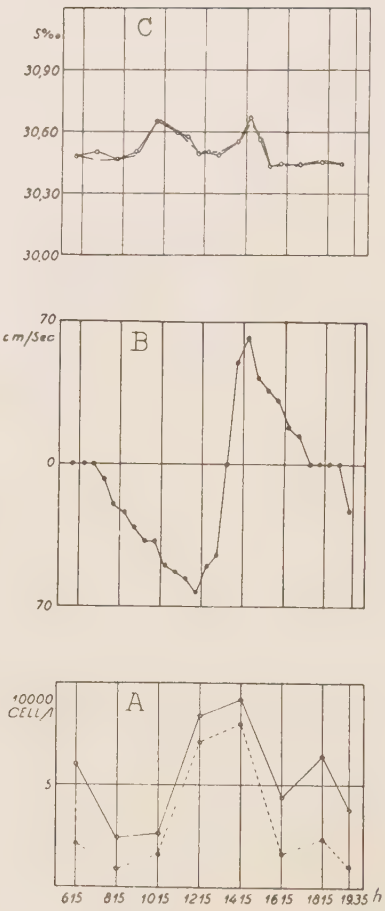

Fig. 11.

Figs. 9—11. St. 4, Kolby Leje. Fig. 9 — $^{14}/_{7}$; fig. 10 — $^{15}/_{7}$; fig. 11 — $^{28}/_{7}$. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o--o--o bottom diatoms. *B*: Current measurements at the surface. *C*: Salinity. o—o—o surface, •—•—• bottom.

island the present author observed in 1941 such large quantities of *Merismopedia* that in places they produced a strong green colouration of the sand.

On $^{28}/_{7}$ *Rhizosolenia* was the dominant plankton form with greatest frequency at high-water; in the lowwater samples it only occurs sporadically or is quite absent. The variation proceeds in the same rhythm as for *Sceletonema* and the other plankton forms. That the curve for the total number of diatoms has nevertheless its highest point at lowwater is due to the bottom diatoms, which are most abundant in the lowwater samples; these have so great an influence numerically that they determine the main direction of the curve. It may seem surprising that the bottom diatoms, which belong mainly to the inner parts of the Waddensea, as shown by the investigations taken as a whole, do not occur with greater frequency at this lowwater station; probably this is due in the main to the fact, that the bottom in Kolby Leje

constitutes a less favourable substratum for these organisms; the material seems to be poor in mud, the quantity of the mud particles suspended in the water being relatively small.

e. St. 5, Rømø Leje north.

(Tables 10—12; Figs. 12—14).

From this station we have in all 23 samples, 8 from $^{14}/_{7}$, 6 from $^{15}/_{7}$ and 9 from $^{28}/_{7}$. The average number of diatoms in the same order is 590,000, 414,000 and 218,000 specimens per litre, with the bottom diatoms contributing 322,000, 282,000 and 155,000 respectively.

The concentration (cells per litre) of the most common diatom species at St. 5, Rømø Leje north.

Table 10. — $^{14}/_{7}$ 41.

Hour	6^{50}	8^{15}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	19^{15}
Asterionella japonica	224,000	146,000	44,000	54,000	46,000	28,000	314,000	290,000
Biddulphia aurita	2,000	6,000	8,000	6,000	14,000	4,000	1,000	4,000
— rhombus	12,000	4,000	2,000	20,000	18,000	8,000	3,800	..
Campylosira cymbelliformis	8,000	..	..	..	..	..	12,000	6,000
Lithodesmium undulatum	18,000	6,000	4,000	6,000	2,000	8,000	16,800	..
Melosira sulcata	..	6,000	..	..	..	10,000	1,200	..
Nitzschia closterium	74,000	84,000	90,000	50,000	28,000	28,000	4,400	36,000
Sceletonema costatum	48,000	68,000	92,000	6,000	52,000	12,000	12,000	22,000

Table 11. — $^{15}/_{7}$ 41.

Hour	7^{15}	8^{15}	10^{15}	12^{15}	14^{15}	18^{15}
Asterionella japonica	12,000	54,000	78,000	20,000	14,000	104,000
Biddulphia aurita	1,600	..	2,000	..	4,000	16,000
— rhombus	12,400	8,000	6,000	8,000	12,000	56,000
Campylosira cymbelliformis	12,000	..	..	..	4,000	..
Lithodesmium undulatum	20,400	2,000	8,000	..	..	8,000
Melosira sulcata	6,400	..	..	..	..	..
Nitzschia closterium	1,200	34,000	26,000	28,000	24,000	48,000
Sceletonema costatum	..	4,000	24,000	..	34,000	52,000

Table 12. — $^{28}/_{7}$ 41.

Hour	5^{40}	6^{15}	8^{15}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	19^{30}
Asterionella japonica	2,000	..	..	..	8,000	2,000	10,000	81,000	34,000
Biddulphia aurita	..	1,000	..	..	8,000	2,000	..	..	..
— rhombus	..	..	2,000	6,000	18,000	10,000	6,000	4,000	2,000
Campylosira cymbelliformis	..	..	..	..	14,000	3,000	..	..	..
Guinardia flaccida	..	..	..	..	..	..	..	2,000	..
Lithodesmium undulatum	2,000	23,000	4,000	..	..	2,000	..	..	12,000
Melosira sulcata	..	..	..	..	..	6,000	..	..	..
Nitzschia closterium	8,000	8,000	6,000	4,000	..	2,000	8,000	4,000	6,000
Rhizosolenia Shrubsolei	44,000	21,000	6,000	2,000	..	..	12,000	88,000	2,000
Sceletonema costatum	10,000	..	..	12,000	4,000	6,000	..	6,000	26,000

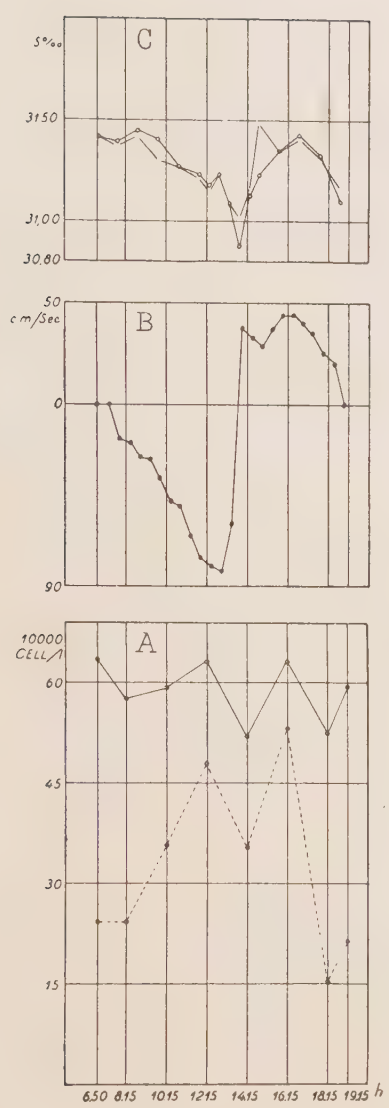

Fig. 12.

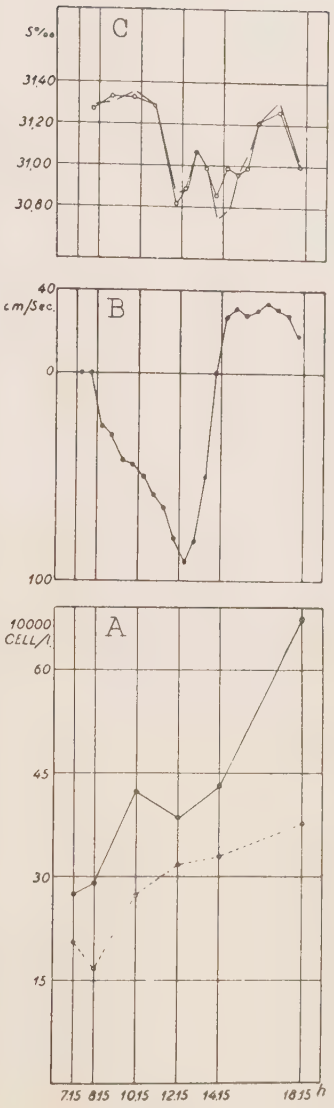

Fig. 13.

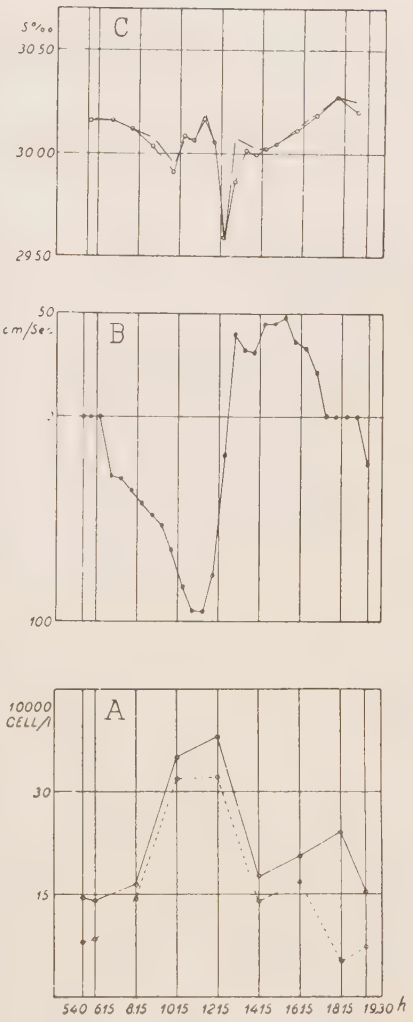

Fig. 14.

Figs. 12—14. St. 5, Rømø Leje north. Fig. 12 — $^{14}/_{7}$; fig. 13 — $^{15}/_{7}$; fig. 14 — $^{28}/_{7}$. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o - - o - - o bottom diatoms. *B*: Current measurements at the surface. *C*: Salinity. o—o—o surface, •—•—• bottom.

On $^{14}/_{7}$ *Asterionella* is the dominant species; its quantities show the same variation as at the previous stations, being greatest at highwater. *Sceletonema* and *Nitzschia closterium* have specially high numbers in the outgoing current; *Biddulphia rhombus* is most abundant at low-water. The number of bottom diatoms increases greatly about the change of ebbtide, but the curve shows a partial minimum just at full ebb; this is due possibly to a southgoing "rest current"[1]). As the water was relatively high on $^{14}/_{7}$, such a current would have a marked effect at St. 5, since it came from areas with smaller density of diatoms. The plankton forms and

[1]) According to LUNDBAK such a "rest current" is running (though rather irregularly) inside the islands Rømø, Mandø and Fanø about tide changes; at high water it runs northward, at low water southward.

bottom diatoms vary in such a manner that the total amount is practically the same in all samples.

On $^{15}/_{7}$ the same species are present in the plankton, but the number of specimens is much lower with the outgoing current. The curve for the bottom diatoms rises uniformly from the change of tide in the morning to the change in the afternoon. The very different shape of the curve for the total number of diatoms from that of $^{14}/_{7}$ is possibly due to a north-going "rest current" round about highwater, contributing to the peculiar variation in quantity, characterised by a relatively small number of plankton forms after the morning change of tide and a large number of bottom diatoms in the water-masses at the afternoon change. The amount of water in the "rest current" is certainly small by comparison with the main tidal current, when the amounts are reckoned on the basis of the incoming and outgoing currents in the main water-courses (cf. LUNDBAK); but in a shallow water area like Rømø Leje, through which the whole mass of water carried by the northgoing "rest current" from Lister Dyb to Juvre Dyb passes, it may make itself specially felt, so much so that it causes considerable changes in the plankton flora at the place where St. 5 is situated.

On $^{28}/_{7}$ the plankton diatoms with *Rhizosolenia* as dominant species are most abundant at highwater, the bottom diatoms at lowwater; the quantities of the latter preponderate so much, that the curve for the total material has a distinct maximum round the change at ebbtide.

The bottom diatoms are represented in greater numbers in the samples from St. 5 than from any of the other stations where synchronous collections were made; very high numbers were also found at St. B in Rømø Leje where samples were taken on $^{17}/_{7}$; it seems right to conclude from this, that the stock of these organisms must be specially rich at the bottom of Rømø Leje.

f. St. 6, Juvre Dyb.

(Tables 13—15; Figs. 15—17).

The collection contains in all 22 samples, 6 from $^{15}/_{7}$ and 8 from each of the other days of collection. The average number of diatoms on the 14, 15, and 28, July is respectively 452,000, 461,000 and 259,000 specimens per litre, with the bottom diatoms contributing 138,000, 179,000 and 53,000.

The fluctuation of the plankton is on the whole somewhat irregular; from the position of St. 6, on the south side of Juvre Dyb just at the place where the Deep divides into a northern and southern branch, it is not surprising, as the plankton at St. 5 and St. 7, which lie innermost in the two branches, is rather different. Further, LUNDBAK notes, that at St. 6 in Juvre Dyb certain hydrographical irregularities occur, partly due to shifting of deposits, partly to the formation of whirlpools; it is possible, that these conditions are also reflected in the quantitative variation of the plankton.

On $^{14}/_{7}$ *Asterionella* is the dominant form with greatest concentration during the outgoing current, a condition that is presumably connected with a great influx of North Sea water into the Waddensea on $^{14}/_{7}$, so that the area with the denser occurrence was pushed inwards, also to some extent with the fact, that the species was abundant in Mandø Dyb during the period of observation. The *Biddulphia* species, *Lithodesmium undulatum*, *Melosira sulcata*, *Nitzschia closterium* and *Sceletonema costatum* show maximum occurrence at lowwater; *Lithodesmium*, which was most abundant at highwater on St. 5, is absent here in the highwater samples; as it occurs during lowwater, its actual distribution must lie between these two stations, from which it extends northwards inside the stations 7 and 8, as will be seen later.

The concentration (cells per litre) of the most common diatom species at St. 6, Juvre Dyb.

Table 13. — $^{14}/_{7}$ 41.

Hour	6^{30}	8^{15}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	20^{15}
Asterionella japonica	428,000	212,000	440,000	202,000	184,500	100,000	110,000	116,000
Biddulphia aurita	..	2,000	4,000	10,000	..	..	..	..
— rhombus	4,000	4,000	6,000	32,000	6,000	4,000	1,000	2,000
Campylosira cymbelliformis	18,000	22,000	12,000	18,000	10,000	8,000	14,000	..
Lithodesmium undulatum	..	..	10,000	4,000	48,000	..	..	..
Melosira sulcata	..	..	12,000	..	6,000	..	..	..
Nitzschia closterium	8,000	14,000	36,000	62,000	42,000	14,000	7,000	16,000
Rhizosolenia Shrubsolei	6,000	2,000	2,000	..	..	14,000	18,000	26,000
Sceletonema costatum	..	..	26,000	62,000	46,000	8,000	..	6,000

Table 14. — $^{15}/_{7}$ 41.

Hour	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	20^{15}
Asterionella japonica	379,000	162,000	76,000	195,000	174,000	124,000
Biddulphia aurita	5,000	4,000	4,000	2,000	6,000	4,000
— rhombus	6,000	2,000	2,000	8,000	6,000	..
Campylosira cymbelliformis	21,000	16,000	..	26,000	26,000	6,000
Lithodesmium undulatum	4,000	36,000	18,000	..	..	..
Melosira sulcata	..	..	10,000	10,000	..	22,000
Nitzschia closterium	37,000	32,000	2,000	14,000	28,000	8,000
Rhizosolenia Shrubsolei	17,000	6,000	2,000	12,000	8,000	2,000
Sceletonema costatum	23,000	56,000	4,000	32,000	6,000	8,000

Table 15. — $^{28}/_{7}$ 41.

Hour	6^{30}	8^{15}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	19^{10}
Asterionella japonica	30,000	47,000	100,000	41,000	58,000	43,000	17,000	12,000
Biddulphia aurita	1,000	1,000	..	1,000	..	..	3,000	1,000
— rhombus	..	2,000	3,000	4,000	..	..	..	..
Campylosira cymbelliformis	6,000	9,000	8,000	3,000	10,000	2,000	9,000	5,000
Guinardia flaccida	5,000	..	3,000	2,000	4,000	2,000	5,000	2,000
Lithodesmium undulatum	..	..	4,000	..	8,000	4,000	..	..
Melosira sulcata	4,000	..	..	..	4,000	..	..	..
Nitzschia closterium	5,000	9,000	4,000	21,000	7,000	8,000	..	4,000
Rhizosolenia Shrubsolei	150,000	191,000	86,000	4,000	128,000	125,000	173,000	214,000
Sceletonema costatum	..	..	3,000	..	..	3,000	6,000	..

On $^{15}/_{7}$ the series of samples does not cover a whole tidal period and the plankton variation is difficult to understand; this is due especially to the very abundant sample from 16.15 hours. If there has been no mistake in the labelling, an exchange perhaps with the sample from 20.15 hours, the above noted hydrographical conditions may be considered as an essential cause of the unclear picture shown by the plankton variation, both as a whole and in a number of details.

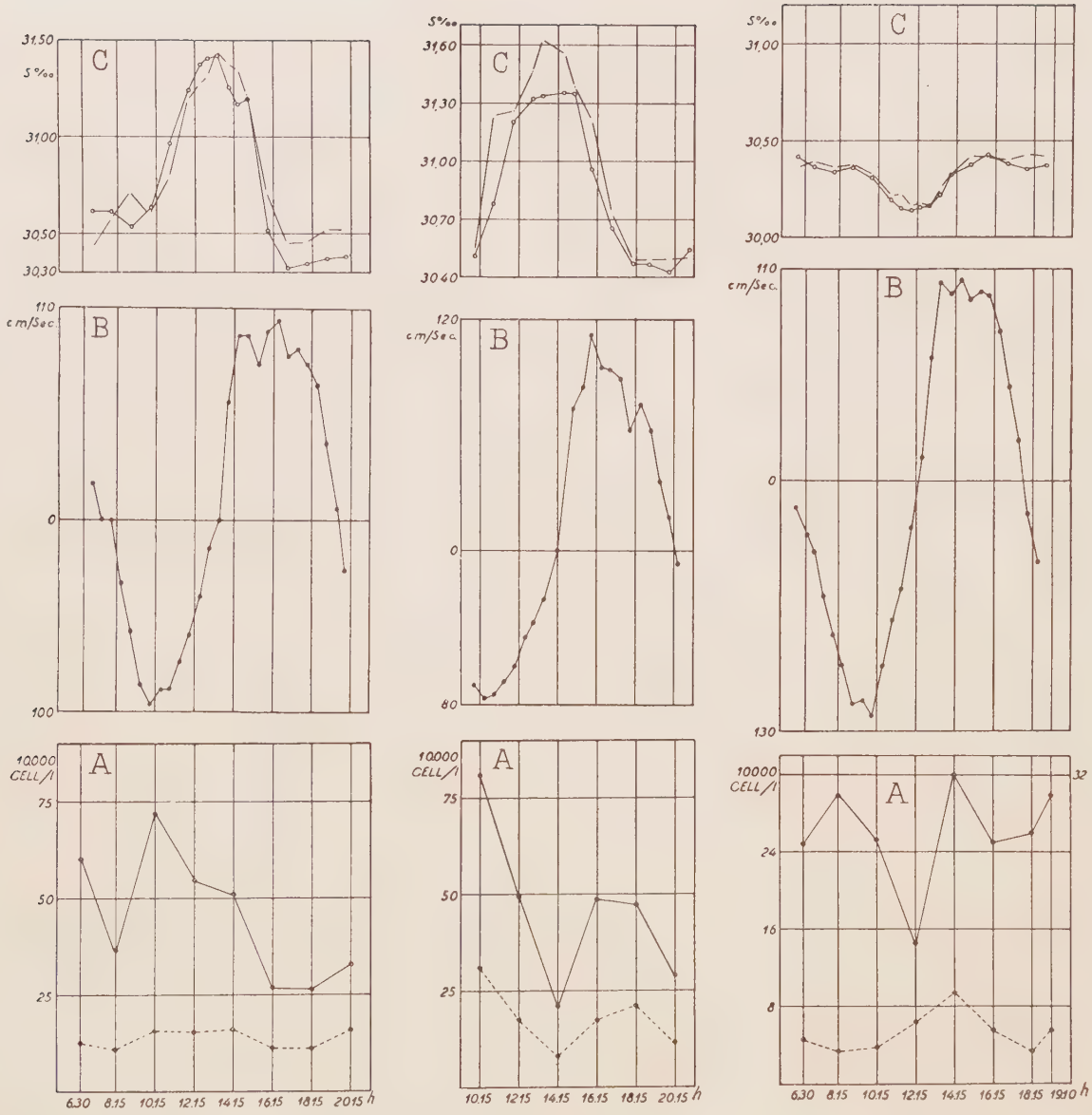

Fig. 15. Fig. 16. Fig. 17.

Figs. 15—17. St. 6, Juvre Dyb. Fig. 15 — $^{14}/_{7}$; fig. 16 — $^{15}/_{7}$; fig. 17 — $^{28}/_{7}$. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o--o--o bottom diatoms. *B*: Current measurements at the surface. *C*: Salinity. o—o—o surface, •—•—• bottom.

On $^{28}/_{7}$ *Rhizosolenia* is the dominant species with greatest concentration during high-water; at lowwater there is only a trace of it; the plankton in this sample shows therefore a distinct minimum, whilst the values in the other samples are fairly uniform.

In regard to the plankton stock there is greater resemblance between the stations 6 and 7 than between 6 and 5; this is noticeable especially in the numerical preponderance of *Asterionella* and *Rhizosolenia* at the first-mentioned stations, whilst the forms more dependent on the bottom, e. g. the *Biddulphia* species and bottom diatoms, preponderate at St. 5.

g. St. 7, Mandø Dyb.

(Tables 16—18; Figs. 18—20).

The material examined consists of 24 samples; of these 8 were collected on $^{14}/_{7}$, 9 on $^{15}/_{7}$ and 7 on $^{28}/_{7}$. The average number of diatoms is respectively 767,000, 435,000 and 123,000 specimens per litre, with 129,000, 109,000 and 29,000 for the bottom diatoms.

In all three days of collection the maximum of the diatom curves occurs during high-water, the numerically prominent species *Asterionella* and *Rhizosolenia* varying in number in

The concentration (cells per litre) of the most common diatom species at St. 7, Mandø Dyb.

Table 16. — $^{14}/_{7}$ 41.

Hour	5^{15}	6^{15}	8^{10}	10^{05}	12^{10}	16^{05}	18^{05}	19^{05}
Asterionella japonica	568,400	700,000	861,000	647,000	96,000	432,000	547,000	584,000
Biddulphia aurita	800	3,000	1,000	6,000	2,000	1,500	3,000	4,000
— rhombus	2,400	5,000	2,000	2,000	10,000	10,500	6,000	3,000
Campylosira cymbelliformis	..	6,000	12,000	8,000	..	..	14,000	15,000
Lithodesmium undulatum	1,600	..	4,000	22,000	38,000	10,500	2,000	..
Melosira sulcata	3,200	..	..	..	..	..	..	8,000
Nitzschia closterium	4,400	23,000	25,000	53,000	5,000	17,000	23,000	17,000
Rhizosolenia Shrubsolei	1,600	4,000	..	2,000	..	..	..	1,000
Sceletonema costatum	9,600	45,000	31,000	47,000	18,000	18,000	62,000	17,000

Table 17. — $^{15}/_{7}$ 41.

Hour	5^{10}	6^{10}	8^{05}	10^{07}	12^{00}	14^{10}	16^{05}	18^{00}	19^{05}
Asterionella japonica	180,000	218,000	333,000	286,000	110,000	48,000	92,000	188,000	603,000
Biddulphia aurita	5,000	2,000	..	1,000	..	..	800	1,000	1,500
— rhombus	3,000	10,000	3,000	3,000	6,000	6,000	6,800	5,000	..
Campylosira cymbelliformis	..	3,000	..	..	9,000	..	..	..	10,500
Lithodesmium undulatum	50,000	23,000	7,000	51,000	96,000	122,000	96,000	27,000	9,000
Melosira sulcata	2,000	..	..	..	..	..	2,400	5,000	..
Nitzschia closterium	11,000	22,000	36,000	24,000	14,000	6,000	400	20,000	18,000
Rhizosolenia Shrubsolei	..	1,000	6,000	..	1,000	6,000	..	..	4,500
Sceletonema costatum	9,000	57,000	12,000	15,000	4,000	..	..	..	15,000

Table 18. — $^{28}/_{7}$ 41.

Hour	6^{07}	8^{07}	12^{08}	14^{09}	16^{07}	18^{08}	20^{10}
Asterionella japonica	42,000	57,000	..	71,000	21,000	51,000	15,000
Biddulphia aurita	..	..	..	..	..	1,000	..
— rhombus	1,000	1,000	4,000	4,000	..	1,000	..
Campylosira cymbelliformis	..	4,000	..	..	3,000	6,000	..
Guinardia flaccida	2,000	..	..	..	..	3,000	1,000
Lithodesmium undulatum	1,000	..	2,000	9,000	5,000	..	..
Melosira sulcata	..	..	..	..	..	6,000	4,000
Nitzschia closterium	4,000	2,000	1,000	8,000	3,000	6,000	2,000
Rhizosolenia Shrubsolei	70,000	48,000	..	14,000	27,000	50,000	139,000
Sceletonema costatum	..	6,000	..	..	12,000	..	..

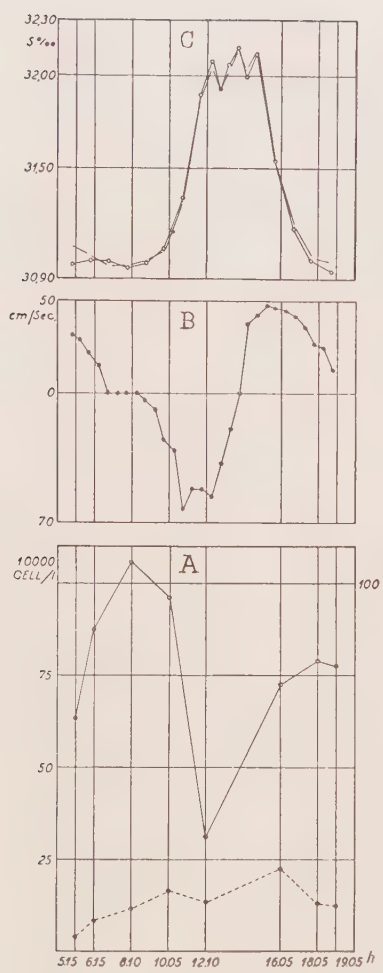

Fig. 18.

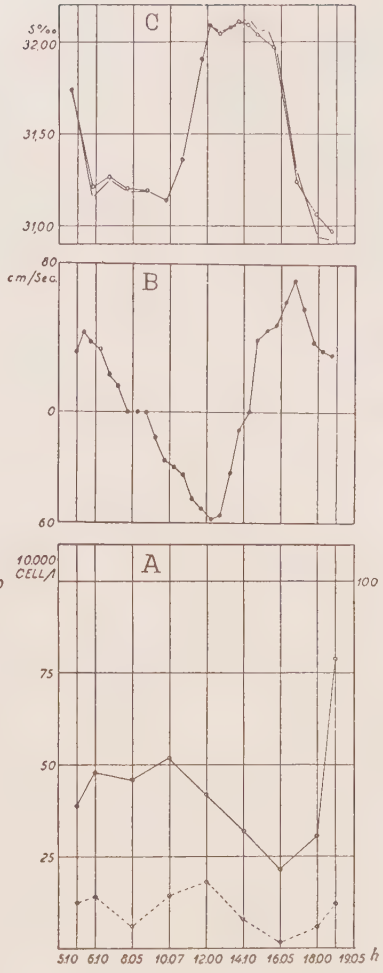

Fig. 19.

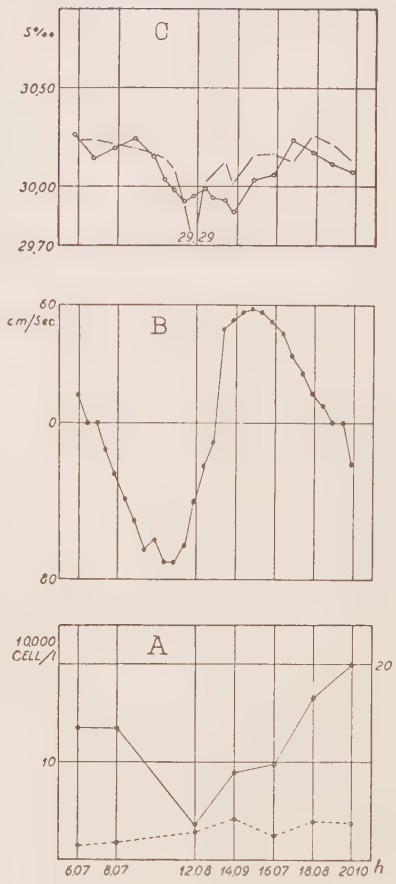

Fig. 20.

Figs. 18—20. St. 7, Mandø Dyb. Fig. 18 — $^{14}/_{7}$; fig. 19 — $^{15}/_{7}$; fig. 20— $^{28}/_{7}$. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o--o--o bottom diatoms. *B*: Current measurements at the surface. *C*: Salinity. o—o—o surface, •—•—• bottom.

such a manner; the lowwater minimum is most distinct for $^{28}/_{7}$, when *Rhizosolenia* is the dominant species, to a less degree on $^{14}/_{7}$ and $^{15}/_{7}$ when *Asterionella* is the most abundant plankton form; this species shows considerable abundance in several of the lowwater samples, as also *Lithodesmium undulatum*.

The frequency curves for the bottom diatoms show a somewhat irregular course, due in the main probably to the watermasses, passing St. 7 in the period of the outgoing current, being on occasion more or less mixed with water coming from the south with a north-going "rest current" over Rejsby Stjert, or with water from the north streaming over the shallow area at Mandø ebb pathway (cf. Lundbak). The stock of bottom diatoms is certainly unequally distributed, both in qualitative and quantitative regards, in the different wad areas. The contents of the water samples from a spot like St. 7, which is surrounded by wads and shallow water areas in a wide circle on three sides, are thus dependent on which wad area the watermasses in question have passed over.

h. St. 8, Knudedyb.

(Tables 19—21; Figs. 21—23).

The material consists of 22 samples, 8 from $^{14}/_{7}$, 7 from each of the other two days; the average number of diatoms on the 14, 15 and 28, July was respectively 867,000, 886,000 and 222,000 specimens per litre, the bottom diatoms showing 324,000, 355,000 and 65,000.

On $^{14}/_{7}$, when much North Sea water had been carried into the Waddensea, the central

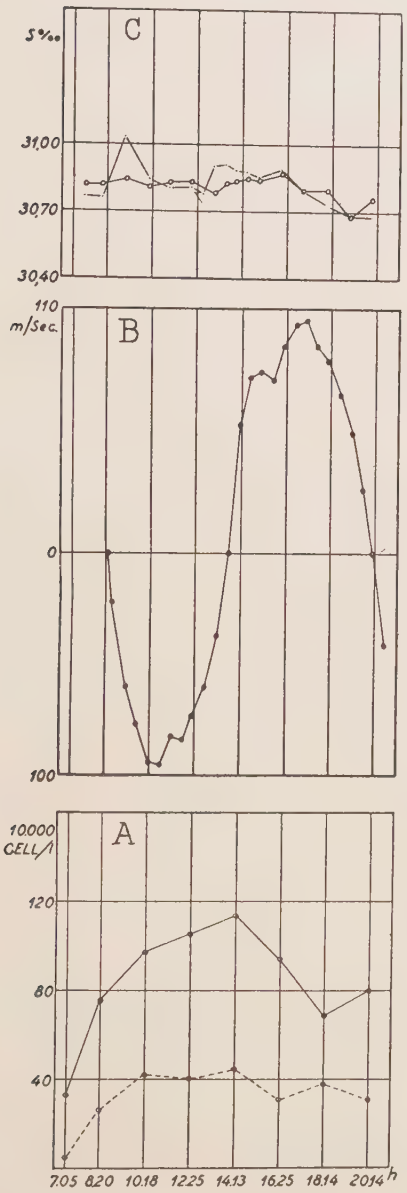

Fig. 21.

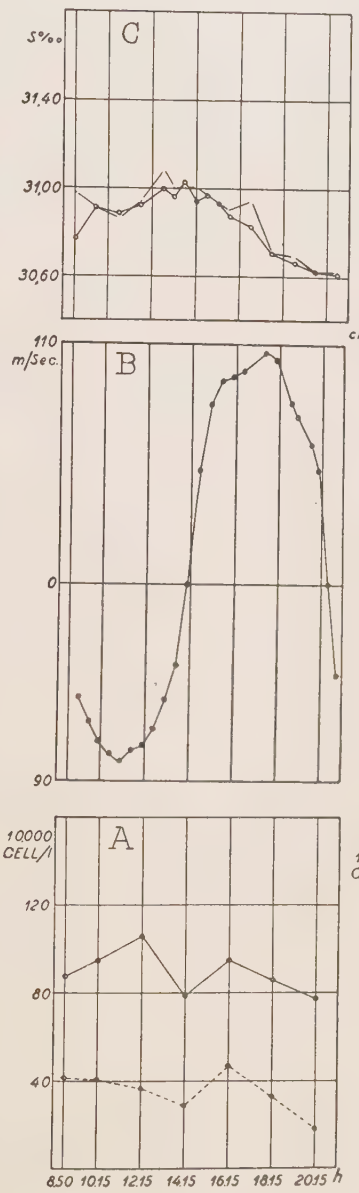

Fig. 22.

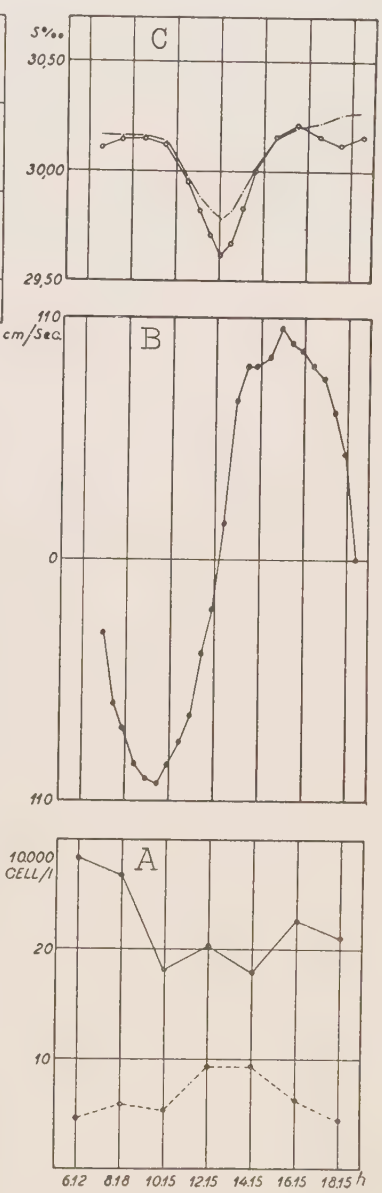

Fig. 23.

Figs. 21—23. St. 8, Knudedyb. Fig. 21 — $^{14}/_{7}$; fig. 22 — $^{15}/_{7}$; fig. 23 — $^{28}/_{7}$. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o--o--o bottom diatoms. *B*: Current measurements at the surface. *C*: Salinity. o—o—o surface, •—•—• bottom.

The concentration (cells per litre) of the most common diatom species at St. 8, Knudedyb,

Table 19. — $^{14}/_{7}$ 41.

Hour	7^{05}	8^{20}	10^{18}	12^{25}	14^{13}	16^{25}	18^{14}	20^{14}
Asterionella japonica	220,000	396,000	390,000	412,000	676,000	468,000	210,000	406,000
Biddulphia aurita	..	..	4,000	6,000	..	..	2,000	2,000
— rhombus	..	2,000	4,000	6,000	10,000	2,000	..	..
Campylosira cymbelliformis	..	16,000	8,000	10,000	6,000	6,000	20,000	..
Chaetoceros debilis	..	..	..	..	14,000	6,000	24,000	..
Guinardia flaccida	4,000	6,000	12,000	6,000	4,000	..	6,000	8,000
Lithodesmium undulatum	14,000	6,000	22,000	32,000	62,000	42,000	..	18,000
Melosira sulcata	..	..	..	..	24,000	..	..	..
Nitzschia closterium	6,000	20,000	30,000	34,000	64,000	26,000	12,000	32,000
Rhizosolenia Shrubsolei	4,000	..	6,000	24,000	18,000	2,000	..	10,000
Sceletonema costatum	22,000	30,000	30,000	76,000	48,000	58,000	6,000	..

Table 20. — $^{15}/_{7}$ 41.

Hour	8^{50}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}	20^{15}
Asterionella japonica	278,000	358,000	586,000	311,000	312,000	446,000	544,000
Biddulphia aurita	2,000	2,000	2,000	1,000	2,000	..	6,000
— rhombus	..	..	2,000	1,000	6,000	2,000	2,000
Campylosira cymbelliformis	18,000	..	..	10,000	6,000	6,000	24,000
Chaetoceros debilis	10,000	..	..	..	..	..	..
Guinardia flaccida	6,000	2,000	4,000	..	2,000	4,000	..
Lithodesmium undulatum	8,000	84,000	50,000	48,000	30,000	18,000	..
Melosira sulcata	6,000	..	..	5,000	..	..	..
Nitzschia closterium	32,000	44,000	22,000	29,000	42,000	34,000	16,000
Rhizosolenia Shrubsolei	6,000	20,000	16,000	2,000	18,000	6,000	2,000
Sceletonema costatum	6,000	20,000	..	71,000	46,000	14,000	..

Table 21. — $^{28}/_{7}$ 41.

Hour	6^{12}	8^{18}	10^{15}	12^{15}	14^{15}	16^{15}	18^{15}
Asterionella japonica	8,000	2,000	24,000	2,000	4,000	12,000	20,000
Biddulphia rhombus	..	2,000	2,000	10,000	4,000	..	..
Campylosira cymbelliformis	..	6,000	..	..	5,000	6,000	6,000
Chaetoceros debilis	86,000	20,000	..	..	..	38,000	46,000
Guinardia flaccida	4,000	4,000	6,000	..	..	2,000	2,000
Lithodesmium undulatum	..	..	2,000	..	2,000	2,000	..
Melosira sulcata	..	..	..	16,000	..	10,000	..
Nitzschia closterium	6,000	6,000	8,000	6,000	..	2,000	6,000
Rhizosolenia Shrubsolei	132,000	144,000	78,000	60,000	70,000	73,000	84,000
Sceletonema costatum	..	..	8,000	..	..	..	..

area for the occurrence of the dominant species, *Asterionella*, had penetrated inwards beyond St. 8, as can be seen from the greater frequency of the species at lowwater; the same applies to all the other abundant species and the diatom curve thus shows a distinct maximum at the change of ebbtide.

On $^{15}/_{7}$ the range of the variation is less, chiefly owing to the more uniform occurrence of *Asterionella* in the samples; the main centre of this species now obviously lies round St. 8, whereas a species like *Sceletonema costatum* still has its greatest concentration inside.

On $^{28}/_{7}$ *Rhizosolenia* is the dominant species; its occurrence during the tidal changes shows, that the area with greatest density lies outside St. 8, but not too far away to have considerable frequency in the lowwater samples. On the other hand, *Chaetoceros debilis* is developed farther out, as it only appears in the highwater samples. The total result of the quantitative variation of the diatoms is a minimum at lowwater, which, however, is not very distinct owing to the maximum for the bottom diatoms at this phase.

In the Knudedyb area collections were only made at this one station, and the quantity of diatoms in the inner parts was not directly investigated, as was the case in the two tidal areas farther south. From the quantitative variation of the diatoms on 14, and 15, July we obtain some information regarding the occurrence of the species in the immediate vicinity. Comparison of the average frequencies on the two days gives further evidence, that St. 8 had a development of plankton just as rich as immediately outside, the plankton quantities being almost the same on the two days and thus not essentially influenced by the stronger influx of water from the outside on $^{14}/_{7}$; at other stations, on the other hand, especially St. 3 and St. 7, the average number of diatoms was higher on the 14, than on the 15, July.

That the bottom diatoms at St. 8 have a relatively high frequency figure in the plankton samples may be considered to indicate, that these species form dense stocks on the bottom in the shallower parts round this station and in the inner parts of the Knudedyb tidal area. As it seems to be a general rule, that the density of the bottom diatoms increases with the amount of mud in the uppermost bottom layer, we may believe that these species are mainly brought into suspension in the muddier parts and we should therefore expect, that the mud content was also specially large in the samples from this station. This is so far from being the case, that we even find here a smaller amount of mud than at any of the other stations. The explanation is presumably, that the bottom diatoms here (as shown elsewhere; cf. p. 42) protect the bottom from erosion by the water.

2. Investigations 17, and 20, July, 1941.

In this section we deal with the plankton from four localities in the area east of Rømø. As the collections were not made at the same time as the foregoing, and the results cannot therefore be compared, they are included here as a special section, as they provide supplementary information regarding the diatom flora in the area in question. The plankton diatoms are relatively few in numbers and the frequency of the various species in the single samples is therefore omitted. The average frequency is shown in Table 22, the quantitative variation during the tidal periods in Figs. 24—27.

a. St. E, "Blindtarmen" (Blind alley).

(Table 22; Fig. 25).

On $^{17}/_{7}$ 6 plankton samples were collected at St. E; the average number of diatoms in these is 415,000 specimens per litre, the bottom diatoms accounting for 109,000. The flora is characterised by the great predominance of *Asterionella japonica*, which shows decreasing

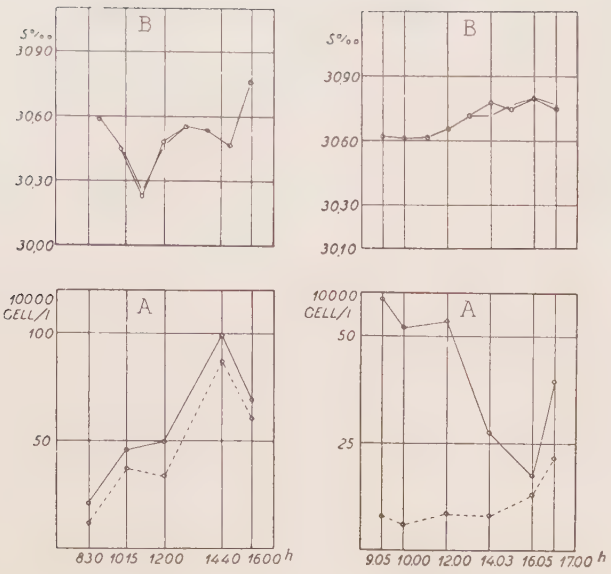

Fig 24.

Fig. 25.

Fig. 24. St. B, Rømø Leje — $^{17}/_{7}$ 41. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o--o--o bottom diatoms. B, Salinity. o—o—o surface, •—•—• bottom. Current change from outgoing to ingoing tide at 16^{33} hours.

Fig. 25. St. E, "Blindtarmen" — $^{17}/_{7}$ 41. *A*: Number of diatoms in the surface water. o—o—o all diatoms, o--o--o bottom diatoms. *B*: Salinity. o—o—o surface, •—•—• bottom. Current change from outgoing to ingoing tide at 15^{50} hours.

frequency during outgoing current; the total quantitative variation has the same tendency, even when the bottom diatoms vary in the opposite direction.

b. St. B, Rømø Leje.

(Table 22; Fig. 24).

At this station 5 samples were collected on $^{17}/_{7}$; the average number of diatoms in these was 567,000 specimens per litre, the bottom diatoms being predominant with 458,000 specimens.

The flora at St. B differs from that of the foregoing mainly by the low frequency of the pelagic species *Asterionella* and *Rhizosolenia* and by the greater frequency of tychoplankton forms and bottom species; the high figure for the last shows, that the species of this group have good opportunities for thriving at the bottom in Rømø Leje.

The samples were taken on the outgoing current and the diatom curve shows a rise, though uneven, towards the change of ebbtide. The course of the curve is determined exclusively by the bottom diatoms, the other species showing no numerical variation.

c. St. 3 b, Havneby east.

(Table 22; Fig. 26).

On $^{20}/_{7}$ at St. 3b we collected 7 samples, which showed an average diatom content of 92,000 specimens per litre, including 29,000 bottom diatoms.

The most abundant plankton forms, *Asterionella* and *Rhizosolenia*, have maximum density at highwater; the diatom curve shows a peak corresponding to this, but also one at the change of ebbtide in the morning, owing partly to the relatively large abundance of the bottom diatoms at this time.

The low average at St. 3b may seem remarkable, considering that this station lies near St. 3 where on 14, and 15, July we found a very rich diatom flora. According to Lundbak the hydrographical conditions at these stations are in so far different because the water streaming out of Rude Dyb makes itself felt at St. 3, but not at St. 3b. This circumstance can hardly contribute to an increased diatom content at St. 3, as the Rude Dyb receives much water from the diatom-poor area Kolby Leje. The large number of specimens of bottom diatoms and tychoplankton at St. 3 may thus be considered to come from the lowwater area just to the south and east of this station; the water-masses from there do not pass St. 3b and this is apparently an important cause of the difference in density of bottom forms at the stations 3 and 3b. The

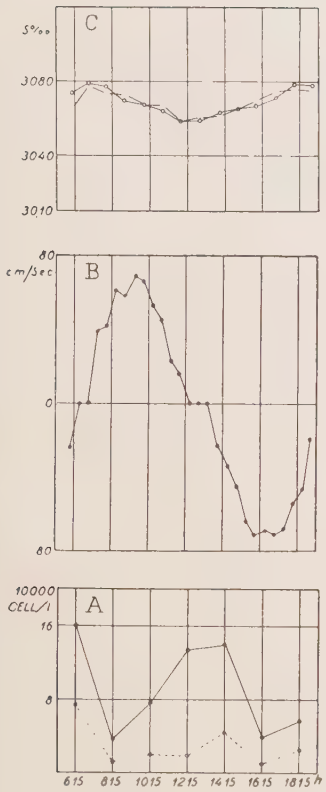

Fig. 26.

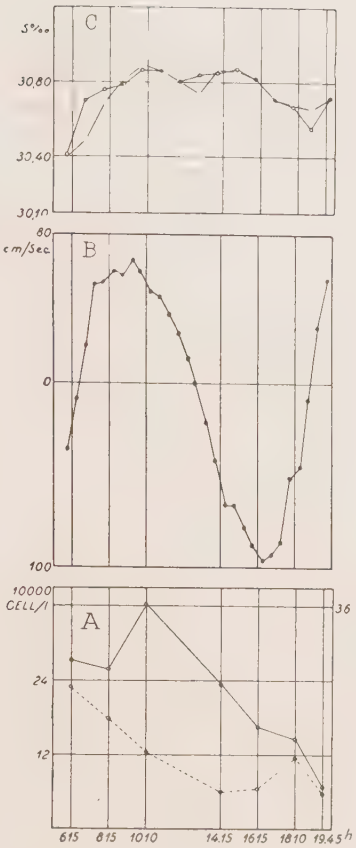

Fig. 27.

Fig. 26. St. 3b, Havneby east — $^{20}/_{7}$ 41.

Fig. 27. Juvre Dyb east — $^{20}/_{7}$ 41.

A: Number of diatoms in the surface water. o—o—o all diatoms, o--o--o bottom diatoms. B: Current measurements at the surface. *C*: Salinity. o—o—o surface, •—•—• bottom.

very low frequency figure for *Asterionella* certainly indicates, that in the latter half of July this species was in a rapidly declining flowering period.

d. St. 5 a, Juvre Dyb east.

(Table 22; Fig. 27).

From the collections of $^{20}/_{7}$ we have 7 samples; the average number of diatoms is 216,000 specimens per litre, and of these 119,000 are bottom diatoms.

The dominant species is *Asterionella* which in the sample at 10.10 hours had a density of 132,000 specimens; at 14.45 hours the density was 120,000. The skew form of the diatom curve is due mainly to the sample taken between the two mentioned being lost; it would undoubtedly have shown such a large frequency for *Asterionella*, that the peak of the curve would have approached nearer to the highwater change. The bottom diatoms have their maximum at the ebbtide changes.

Of the plankton stations discussed in this section St. E and St. 3b lie in the tidal waters of Lister Dyb, St. 5a in the southern branch of Juvre Dyb and St. B in the border area between those two tidal waters (cf. Fig. 2). Comparing the diatom stock at these four stations, and omitting the pelagic species *Asterionella* and *Rhizosolenia*, which show great temporal changes in numbers during the period investigated and thus cannot be used in this comparison as the collections were not synchronised, it is evident that the frequency figures are greatest at St. B, somewhat less at St. E and St. 5a and least at St. 3b; this is in agreement both with the depth of water at these stations and with the previously mentioned circumstance, that Rømø Leje is an important area for the production of "wad-diatoms". That these have greater density at St. 5a than at St. 3b is due presumably to the hydrographical conditions, among which the north-going "rest current" inside Rømø may be considered to have special importance.

Table 22. Average numbers (cells per litre) of organisms in the water samples from the stations E, B, 3b and 5a, $^{17}/_{7}$ and $^{20}/_{7}$, 1941.

Station	E	B	3b	5a
Date	$^{17}/_{7}$	$^{17}/_{7}$	$^{20}/_{7}$	$^{20}/_{7}$
Number of samples	6	5	7	7
Diatomeae.				
Actinoptychus undulatus	33	..	..	..
Asterionella japonica	204,000	20,800	28,000	54,857
Aulacodiscus argus	367	..	..	..
Auliscus sculptus	667	2,400	200	..
Biddulphia aurita	3,667	6,400	571	2,286
— regia	..	..	143	..
— rhombus	7,000	15,600	2,571	5,429
— sinensis	33	..	..	..
— sp.	2,000	2,000	..	1,971
Campylosira cymbelliformis	1,333	2,000	486	1,714
Cerataulus turgidus	333	400	..	..
Chaetoceros densus	6,000	..	1,714	..
— sp.	667	..	..	..
Coscinodiscus sp.	..	400	..	..
Grammatophora marina	..	400	..	..
Guinardia flaccida	..	..	571	..
Lithodesmium undulatum	3,833	22,800	2,286	3,857
Melosira sulcata	2,000	5,400	2,286	2,857
Nitzschia closterium	15,000	17,200	3,714	12,714
Rhizosolenia Shrubsolei	6,667	400	12,914	1,429
Sceletonema costatum	51,667	12,400	7,429	10,000
Triceratium favus	333	..	143	..
— sp.	..	160	..	..
Bottom diatoms	109,333	458,400	29,143	118,857
All diatoms	**414,933**	**567,160**	**92,171**	**215,971**
Dinoflagellatate.				
Ceratium fusus	..	..	..	571
Gymnodinium sp.	1,333	..	..	286
Peridinium sp.	333	..	..	..
Cyanophyceae.				
Merismopedia sp. (Col.)	333	..	..	286
Ciliatae				
Helicostomella subulata	700	..	57	286
Tintinnopsis beroidea	1,333	1,600	..	429
— tubulosa	667	..	..	571
— sp.	667	800	..	571
Laboea conica	333	1,200	..	1,286
— vestita	1,667	160	2,571	857
— sp.	..	80	571	1,829
Lohmanniella oviformis	333	..	714	..

IV. Occurrence of the commonest diatoms.

1. *Asterionella japonica* Cleve.

In the southern North Sea the maximum development of this species generally takes place in February to May, but sudden maxima are often observed in the summer half-year; it is but little sensitive to changes in the salinity of the water and belongs therefore to the group of species which can penetrate into more or less brackish coastal waters.

In 1941 *Asterionella* had a flowering period in the middle of July and is at this time the most abundant plankton form in the area investigated. Considering its occurrence in and inside Rømø Dyb it is obvious, that the concentration — expressed as the average number of specimens in a litre of water — decreases greatly in the second half of July. The average figures are:

St. 3; $^{14}/_{7}$	1,017,285	St. 3b; $^{20}/_{7}$	28,000
St. 3; $^{15}/_{7}$	632,000	St. 3; $^{28}/_{7}$	69,375
St. E; $^{17}/_{7}$	204,000		

These values certainly do not show a uniform decrease, but the position of the stations must be taken into account, as also the current conditions and the fact, that the sample series do not cover exactly equally long periods. The density of the species is greatest in Rømø Dyb; it penetrates farther in here than in Højer Dyb, as can be seen both from the average frequency, which is essentially higher at St. 3 than at St. 2, and from the fact, that the relative frequency in the lowwater samples is greatest at St. 3. In the tidal waters of Knudedyb the main centre is round St. 8, as is shown by the greatest frequency at lowwater on $^{14}/_{7}$ when the wind was westerly, whilst the frequency figures for $^{15}/_{7}$ — with easterly wind — were distributed fairly evenly over the different phases of the tidal period, as also by the fact, that the average density is the same for the two days, in spite of the somewhat different state of the water. In the Juvre Dyb area the general distribution of the species seems to have an inner boundary between stations 6 and 7; at the inner stations 4 and 5 the density is low, especially in the lowwater samples. Altogether it may be said, that *Asterionella* was widespread during the period of observation, though with steadily diminishing density, in the outermost zone of the Waddensea; farther in the frequency decreases, although the species is not wholly absent even in the inner parts (cf. Fig. 28).

2. *Biddulphia aurita* (Lyngb.) Breb. et God.

This littoral species has a general distribution over the whole Waddensea and it may occur also in bays with fairly low salinity, as in the Zuiderzee; in the winter and spring months it may give off pelagic specimens and may even be the dominant species in the plankton; for the rest of the year it is found at the bottom and only occurs by chance in the free water-masses; it is widely distributed in wad sediments, though seldom found there in great numbers.

The occurrence of the species in our area is represented in Fig. 29, from which it will be seen that in the Lister Dyb area it has greatest frequency at St. 3, less numerous at St. 4 farther into the Waddensea, whilst in the Juvre Dyb section it is more abundant at St. 5 than at St. 6. Studying the average figures for $^{14}/_{7}$ and $^{15}/_{7}$ we find agreement between the outer

stations 3, 6 and 8, the frequency being smaller on 14, than on 15, whilst the inner stations 4, 5 and 7 show the highest frequency on 14; as already mentioned, the westerly wind on $^{14}/_{7}$ carried relatively large masses of water into the Waddensea; in this way the area for *B. aurita*'s greatest density was moved inside the outer stations, and the frequency figures rise accordingly at the inner stations; on $^{15}/_{7}$ when an east wind exerted its influence on the water level, the frequency figures are relatively high at the outer stations, low on the inner. The picture shows, that the main distribution of the species lies in the outer part of the Waddensea in a zone round the stations 3, 6 and 8; at the stations 4 and 5 the frequency figures show a difference characteristic of the species bound to the bottom. The figures are lower at St. 4 than at St. 5; the explanation of this may probably be, that the wad bottom in Kolby Leje is less suitable as substratum for littoral species than the surroundings of St. 5.

3. *Biddulphia rhombus* (Ehr.) W. Sm.

A littoral species which in the typical form — and more frequently as var. *trigona* — is distributed over the whole Waddensea and also in adjacent waters, *e. g.* Zuiderzee; its frustules are fairly numerous in sediments. In the coastal zone of the North Sea outside the limits of the Waddensea it occurs winter and spring in considerable quantities; thus, Wulff (1935, p. 343) gives it in May as the most characteristic species of the North Friesian coastal water, which includes a zone outside the Waddensea from the mouth of the Elbe to the north end of Rømø.

The occurrence of the species in our waters is illustrated by the average frequency figures, as represented in Fig. 30. In the Lister Dyb section its distribution resembles that of the preceding species, with greatest density at St. 3 and just inside; in the sessile condition it probably is not abundant in Kolby Leje, to judge from its small numerical occurrence in the water samples of St. 4. In the Juvre Dyb at St. 5 it shows greatest frequency in the lowwater samples of $^{14}/_{7}$ and $^{28}/_{7}$ and may be supposed to have considerable concentration on the wad in Rømø Leje, as can be seen also from the samples from St. B, $^{17}/_{7}$. At the stations 6, 7 and 8 the quantitative variation of the species becomes more or less apparent with high values in the lowwater samples and there seems no doubt, that the shallower parts of the Waddensea constitute a more important home ground for this species than the outermost boundaries and the coastal zone outside.

4. *Campylosira cymbelliformis* (A. S.) Grun.

The area of distribution of this species is the southern North Sea, where it is specially frequent in the coastal zone; by several naturalists it is considered to have a tychopelagic mode of life (van Goor, 1923, p. 152); its occurrence in our plankton samples is, however different from that of other tychoplankton species (*e. g. Biddulphia aurita* and *B. rhombus*, *Melosira sulcata*), as it shows a relatively large frequency at the outer stations 6 and 8 (see Fig. 31). In agreement with this and with the difference in numbers on $^{14}/_{7}$ and $^{15}/_{7}$ at all stations, the main centre of distribution of the species may be supposed to cover the outermost Waddensea zone, which runs over the stations 6 and 8, but outside St. 3; farther in the density greatly decreases.

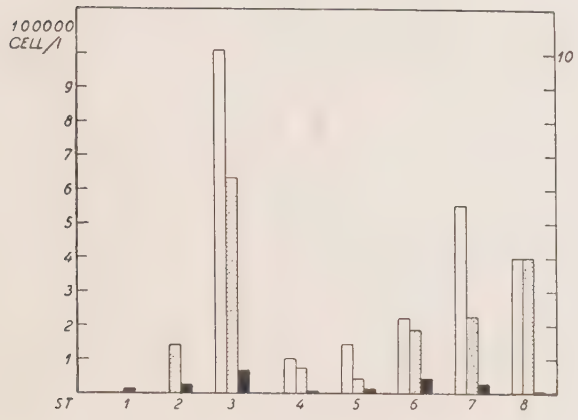

Fig. 28.

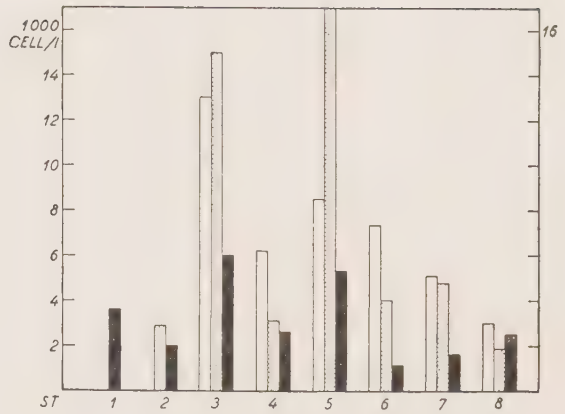

Fig. 30.

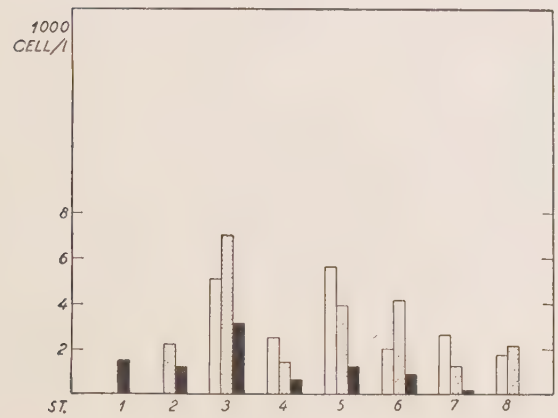

Fig. 29.

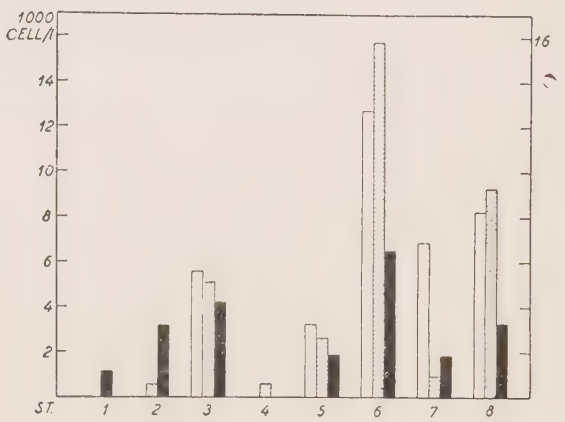

Fig. 31.

Figs. 28—31. Average concentration of different diatoms at Sts. 1—8 in July 1941; white — $^{14}/_{7}$, dotted — $^{15}/_{7}$, black — $^{28}/_{7}$. Fig. 28: *Asterionella japonica*. Fig. 29: *Biddulphia aurita*. Fig. 30: *Biddulphia rhombus*. Fig. 31: *Campylosira cymbelliformis*.

5. *Guinardia flaccida* (Cast.) Perag.

This species is widely distributed in the North Sea with flowering period in the summer or autumn; as it is holoplanktonic, it also occurs in the plankton in the rest of the year, though in small numbers. It can have considerable frequency in the coastal area outside the Waddensea; thus Wulff (1935, p. 345) states that in May 1933 a plankton community was found off the East Friesian islands, the principal component being *Guinardia flaccida*; further, a *Guinardia* zone extended northwards along the North Friesian islands, to the west of the *Biddulphia rhombus* zone (cf. p. 30). The species is unable to bear even a slight decrease in the salinity; its occurrence in the Waddensea is rather seldom and confined to the outer part.

The distribution in the Danish Waddensea is shown in Fig. 32. In the middle of July it occurs in small numbers at stations 6 and 8; the relatively large frequencies on $^{14}/_{7}$, when there was a strong inflow of water, shows that its occurrence is dependent essentially on currents from outside; this can be concluded also from the greatest frequencies occurring at high-water. On $^{28}/_{7}$ *Guinardia* appears at all stations, though only sporadically at the inner stations

4, 5 and 7; in contrast to *Asterionella*, but like *Rhizosolenia Shrubsolei* (see p. 33) it has considerable frequency at St. 2 in the outermost part of Højer Dyb.

6. *Lithodesmium undulatum* Ehr.

A neritic species distributed along the southern North Sea in the coastal area. In the Waddensea it often composes an important part of the plankton and in sheltered places, like the Jade Bay, it may preponderate in summer; that it can stand low salinities is shown by its abundant occurrence in the Zuiderzee and the mouth of the Weser.

In our area *Lithodesmium* only occurs in greater frequency in the samples from stations 7 and 8 in the middle of July (Fig. 33); it shows greatest frequency at lowwater and its home must therefore be the areas inside these stations; with this agrees the fact, that the average density is smaller on $^{14}/_{7}$ than on $^{15}/_{7}$.

Lithodesmium does not seem to be stationary here, as it has practically disappeared from the plankton by $^{28}/_{7}$. This is hardly due, however, to the stock being carried out by the mixing of Waddensea water with North Sea water; it is more probable, that it always occurs here, but now at the bottom when it escapes observation in the plankton samples. In the Jade Bay it stays constantly without being washed away, although this area is emptied of three-fourths of its water content every ebb. Brockmann (1935, p. 25) connects this condition with the low floating powers of the species and its littoral mode of life.

Lithodesmium has a low density at the stations 2—6 and the fact, that it is always found in many-celled colonies, has the effect that the frequency figures in the single samples are not so exact that anything can be said about correlation between density of specimens and phases of the tides, as at the stations 7 and 8.

7. *Melosira sulcata* (Ehr.) Kutz.

A tychopelagic species common along the coasts of the southern North Sea; apart from occasional occurrences it has only been observed in the North Sea at places where the coastal water dominates. In the Waddensea it is common, but seldom occurs in larger numbers in the plankton. Brockmann (1914, p. 40) states that he has never seen bottom samples where it dominated to such an extent, that there could be talk of a specially strong local vegetation; on the other hand, in the marsh region and on the whole in North Sea deposits it is the commonest of all diatoms; its general occurrence in sediment is due to the valves being very resistant.

The average frequency in the plankton samples is shown in Fig. 34; we see from this a fairly uniform distribution over the whole area on all three days of observation, yet there is a slight tendency to decrease inwards in the Waddensea. The low figures in the various observations (Tables 1—21) do not indicate with certainty how far the concentration varies in a regular manner with the tidal changes.

8. *Nitzschia closterium* (Ehr.) W. Sm.

A cosmopolitan species, common in all our waters; it occurs everywhere in the Waddensea; with regard to the average frequencies reference may be made to Table 25; the occur-

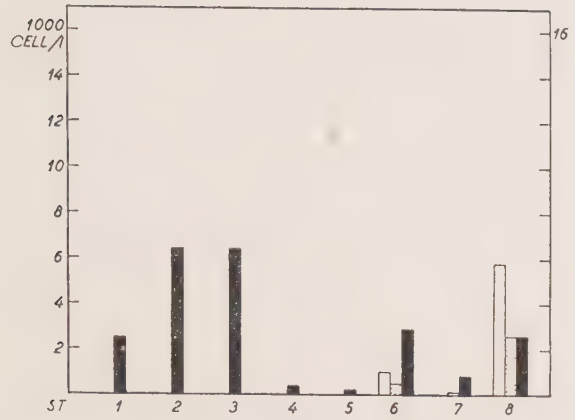

Fig. 32.

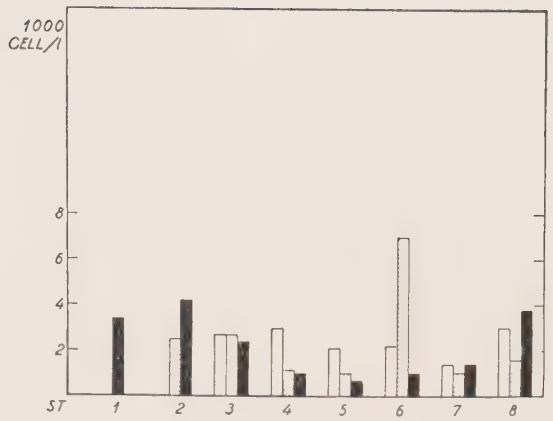

Fig. 34.

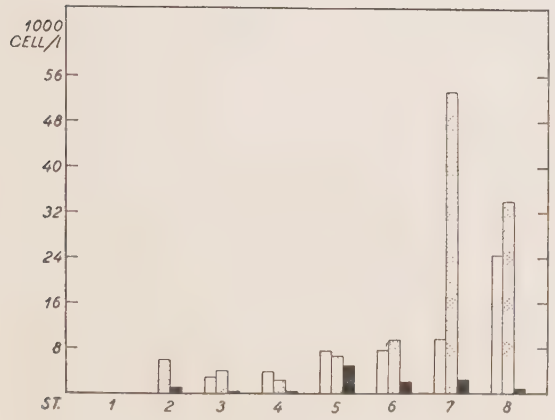

Fig. 33.

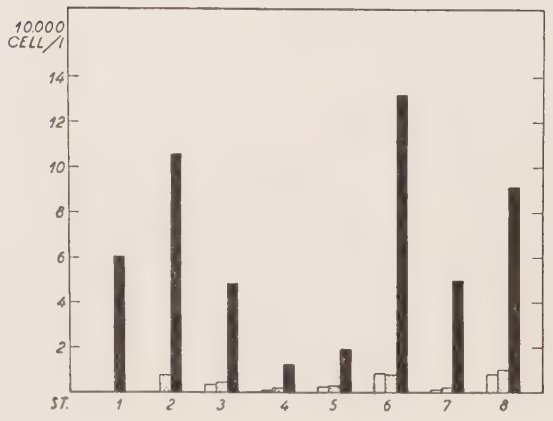

Fig. 35.

Figs. 32—35. Average concentration of different diatoms at Sts. 1—8 in July 1941; white — $^{14}/_{7}$, dotted — $^{15}/_{7}$, black — $^{28}/_{7}$. Fig. 32: *Guinardia flaccida*. Fig. 33: *Lithodesmium undulatum*. Fig. 34: *Melosira sulcata*. Fig. 35: *Rhizosolenia Shrubsolei*.

rence in the single samples is shown in the Tables 1—21. *Nitzschia*'s distribution in the plankton can be illustrated by its average values at the stations 3—8 on 14, 15, and 28, July (excluding stations 1 and 2 as the plankton was not collected here on all three days); from the greatest frequency at St. 5 (27,093 spec. per litre) it decreases at the other stations in the following way: St. 8 (21,286), St. 6 (17,431), St. 3 (14,044), St. 7 (13,820) and St. 4 (6,887); this distribution recalls that of the bottom diatoms (cf. Fig. 38). For the rest *Nitzschia*'s frequency is not nearly so great in these samples as in those taken in Ho Bay in August 1938 (Grøntved, 1940, Fig. 15); here the concentration was greatest in the inner part of the bay which was exposed to the influence of strong freshwater masses from the River Vardeaa.

9. *Rhizosolenia imbricata* var. *Shrubsolei* (Cl.) Schröd.[1])

A holoplankton species with area of distribution in the southern North Sea, where it forms a maximum in the summer half-year; obviously it has its greatest density in areas near

[1]) In Tables and Text shortened to *Rhizosolenia Shrubsolei*.

the coast and occurs in the Waddensea; it can penetrate — though exceptionally — far inwards, as was the case in Jade Bay in August 1930, when it dominated the plankton; in general it is most strongly developed in the outer part.

During the present investigations *Rhizosolenia* was the dominant species in the plankton on $^{28}/_{7}$ but shows only scattered occurrences on $^{14}/_{7}$ and $^{15}/_{7}$ (Fig. 35). That the concentration was on the increase in the latter half of July can be seen from the following average figures per litre at stations in and inside Rømø Dyb:

St. 3, $^{14}/_{7}$	3,514	St. 3b, $^{20}/_{7}$	12,914
St. 3, $^{15}/_{7}$	4,571	St. 3, $^{28}/_{7}$	48,500
St. E, $^{17}/_{7}$	6,667		

Even if these figures cannot be directly compared, since the position of the stations etc. must be taken into account, there is no doubt that *Rhizosolenia* has an incipient flowering during the period of observation. The species has its greatest frequency at the outer stations and shows everywhere a characteristic quantitative variation with greatest density at highwater; it follows from this, that its principal area is the water-masses outside the stations 2, 3, 6 and 8; inwards the frequency greatly decreases and at the stations 4 and 5 the species is lacking in several lowwater samples.

10. *Sceletonema costatum* (Grev.) Cleve.

A neritic species widespread in the coastal area of the southern North Sea; its maximum development takes place as a rule in the early spring, but smaller local flowering periods have also been noticed in the summer months. It has been given from several localities in the Waddensea, without being dominant anywhere, as may be the case elsewhere in localities near the coast.

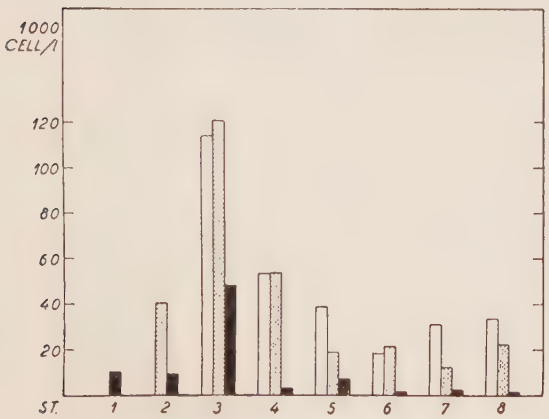

Fig. 36. Average concentration of *Sceletonema costatum* at Sts. 1—8 in July 1941; white — $^{14}/_{7}$, dotted — $^{15}/_{7}$, black — $^{28}/_{7}$.

The occurrence of the species in our area is shown in Fig. 36; it is more abundant on $^{14}/_{7}$ and $^{15}/_{7}$ than on $^{28}/_{7}$; at most of the stations the daily quantitative variation does not show any distinct relation to the tidal periods. On $^{14}/_{7}$ and $^{15}/_{7}$, however, its greatest frequency at St. 4 is during high-water, but at St. 8 in the lowwater samples. On the whole it has less density in the outermost zone of the Waddensea, then follows an inner belt where the density is greater, decreasing again in the inner-most parts; taking cross-sections of the Waddensea we find greatest frequency in the Lister Dyb area, where St. 3 especially shows high figures.

V. Review of the plankton distribution in the Waddensea.

The plankton in the Waddensea is only a part of the suspended matter — "sink-stuff". Under the microscope it becomes obvious that the number of organisms is inconsiderable by comparison with the amount of detritus particles. Actual investigation of the numbers or

quantity of the organisms sharing in the "sink-stuff" has not been undertaken, but it may be mentioned that VAN GOOR (1923, p. 173) estimated the amount of suspended organic detritus in the southern North Sea to be 50—100 times the amount of plankton organisms in the same quantity of water, and there is hardly reason to believe, that the amount of plankton by comparison with the organic detritus is greater in the Waddensea than in the coastal areas outside.

From the tidal area of the Graadyb we have extensive investigations on the water's content of "sink-stuff" and its transport by tidal movements (GRY, 1942). From a special examination of his samples GRY finds, that in Graadyb and the southern part of Ho Bay the sand fraction of the "sink-stuff" varies in a different manner from the mud fraction during the various tidal periods. The sand fraction consists mainly of materials stirred up by the current at the spot and the quantity rises and falls therefore according to the current, so that the curve for the water's content of sand has two peaks corresponding to the current maxima during incoming and outgoing tides; this kind of curve is specially noticeable in the analyses of the bottom material. The other "sink-stuff" fraction, the mud, distinguished from the sand *i. a.* by the smaller size of the particles, varies during a tidal period in such a way, that the quantity is greatest at lowwater. The mud is brought into suspension by the erosive power of the water — mainly in the northern part of Ho Bay; under the mixing of the water-masses it is distributed over the whole bay, but with decreasing density in the southern part and in Graadyb, that is, the farther we get away from the area of erosion the smaller is the mud content of the water (GRY, l. c. Figs. 101, 117). Thus in the course of a tidal period the quantity of mud varies in such a way that the values are greatest at lowwater, that is, it depends on where the water comes from. Yet the quantity of mud is in so far dependent on the strength of the current, that a certain — though small — amount of movement in the water is required to keep the mud particles in suspension; at places where the water was very clouded, MANSHOLT (1909, p. 24) and GRY (l. c.) have observed directly, that the mud disappaears from the uppermost layer of water when the current is still; further, the erosive working of the water which brings the mud into suspension is naturally dependent on the strength of the currents.

The plankton organisms form a component of the "sink-stuff"; from a non-biological standpoint they may be reckoned with the mud fraction. The size of the cells agrees to some extent with the size of some of the mud particles, but is smaller than the commonest sand grains. The floating powers of the cells is increased in a number of forms by the shape of the cell itself or by its appendages: wings, bristles etc. so that they can be held in suspension by feeble currents — just like the mud particles. The diatoms thus show a quantitative variation with the tides that depends on the origin of the water, as will be seen from the accounts of the various stations and Figs. 3—27, where the total amount of diatoms is illustrated graphically; from the variation at the plankton stations one can determine the principal places of occurrence of the diatoms, when the current conditions are known.

To obtain a more exact picture of the distribution of the plankton, however, it is not sufficient to consider only the quantitative variation, a simultaneous investigation of the composition in regard to species is also necessary to throw light on this problem.

Considering the series of species recorded in Table 25 it is evident, that the diatoms make up quite the largest portion of the plankton, both in number of species and number of individuals; it is further characteristic of the Waddensea to show a strong influx of littoral species in the plankton; for this group, however, the number of individuals is not specially large, apart from the true bottom diatoms, which obviously have good possibilities for development on the bottom and thus appear in relatively strong concentrations in the plankton.

In the true plankton the principal components are species which have their strongest concentration in the outermost part of the Waddensea or outside its western boundary; in the middle of July 1941 this group was dominated by the neritic *Asterionella japonica*, at the end of July by the oceanic species *Rhizosolenia Shrubsolei*. In addition to these two species the genuine pelagic flora was represented by a number of neritic forms, *e. g. Biddulphia regia* and *B. sinensis*, *Chaetoceros compressus*, *C. constrictus* and *C. debilis*, *Guinardia flaccida*, *Leptocylindrus danicus*, *Lithodesmium undulatum*, *Sceletonema costatum* and a smaller number of oceanic forms: *Chaetoceros densus*, *C. decipiens*, *Coscinodiscus centralis*, *C. oculus iridis* and others, but only in small numbers.

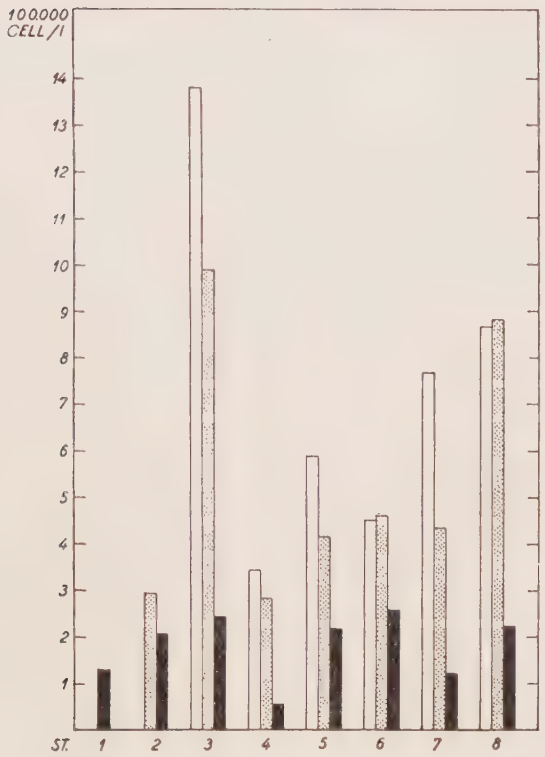

Fig. 37. Average concentration of all diatoms at Sts. 1—8 in July 1941; white — $^{14}/_{7}$, dotted — $^{15}/_{7}$, black — $^{28}/_{7}$.

Fig. 37 shows the average frequencies for all diatoms at the stations where collections were made, 14, 15, and 28, July. The diatom density varies in different parts of the area but shows a clearly decreasing tendency inwards in the Waddensea, but we cannot conclude from this, that a corresponding decrease takes place in the production power of the water, since these figures represent species with very different size of cell; the cells, for example, of *Asterionella japonica* have a much smaller body than the individuals of a majority of the littoral species. *Asterionella* may therefore be expected to show a relatively smaller assimilation intensity than these. But the important question of the production capacity of the water cannot be determined from the available basis; we must have direct investigations on the assimilation.

The variations of salinity, as shown in Figs. 3—27, are small both at the single stations and between the stations. Even if certain species, *e. g. Guinardia flaccida*, react towards the fluctuations indicated, the salt factor is presumably of no essential importance for the described zonation of the diatom stock and we might perhaps expect a stronger evening-out between the plankton in the Waddensea and outside — in consequence of the water movements.

We must, however, distinguish between that part of the plankton which is developed in the inner parts of the Waddensea and the plankton forms with main distribution farthest out in the Waddensea or just outside its boundary. In the first group we find in our investigations *Lithodesmium undulatum* and *Sceletonema costatum* as well as a larger number of tychoplankton species, *e. g. Biddulphia aurita* and *B. rhombus*, *Melosira sulcata*; lastly, reference should be made to the strong occurrence of bottom diatoms in the plankton. All these forms, with stronger or weaker connection with the bottom, can become part of the stock in the Waddensea in spite of the fact that a strong mixing takes place of Waddensea water and North Sea water.

With respect to the genuine plankton forms, with *Asterionella japonica* and *Rhizosolenia Shrubsolei* as the most abundant species, the investigation shows, that they have their densest occurrence in the outer part of the area covered by our samples, then show a rapid decrease

in frequency inwards; in the inner parts of the Waddensea there is probably no production of these species and it is also probable, that sinking is here, at least in parts, relatively great owing to the weaker water movements. In this connection it may be mentioned, that BROCKMANN (1935, pp. 19 etc.) has found that the mud in Jade Bay, which is a well-sheltered area of the German Waddensea, has a higher plankton content than the bottom outside; it would appear that this bay acts as a plankton trap.

It appears further from our investigations, that the Waddensea can also be divided by cross-sections into areas with somewhat different floral characters; they are certainly not sharply distinguished, but easily discerned by the different concentration of some species; *Lithodesmium undulatum*, *Chaetoceros debilis* and other *Chaetoceros* species have their main distribution in the Knudedyb's tidal waters; *Asterionella japonica* here and in the Lister Dyb section; *Sceletonema costatum* is most frequent in the branches of the Lister Dyb. To judge from the concentration in the plankton samples the bottom diatoms may be supposed to form specially rich stocks on the shallow parts of the Knudedyb area and in Rømø Leje (cf. p. 25, 26).

Considering lastly the plankton stock from the point of view of the importance these organisms may have on the wads, that is, the areas which are of special interest in the possible reclaiming of land, certainly all organisms of a chlorophyll nature in the Waddensea contribute through production of organic materials — directly or indirectly — to the formation of mud. The true plankton forms, which are at home in the free waters, are only present in the inner parts in relatively small numbers at the period of highwater and are not found on the wads at ebbtide; these cannot be considered to have great importance in the mudding process — at least not in the stages of bottom formation which is in progress on the wads. The tychoplankton forms, which are connected more or less strongly with the bottom and belong in considerable numbers to the Waddensea itself, are of greater importance in this respect; the most marked bottom-builders are, however, the bottom diatoms, to be discussed in the next chapter.

VI. Bottom diatoms.

1. Plankton forms — Tychoplankton forms — Bottom diatoms.

In the foregoing a distinction has constantly been made between plankton diatoms and bottom diatoms; even where it was a matter of microscopic examination of samples whose organisms were all in suspension in the surface waters when the samples were taken, in biological regards they form two different groups of organisms.

Some of the plankton species live all their lives (holoplankton) as "floaters", *i. e.* suspended in the water, whilst an other group, the meroplankton species, are only pelagic for part of their lives; in the remaining period they are found on the bottom in resting stages. The bottom diatoms normally pass through the whole of their life-cycle at the bottom, whether free, fixed to sand grains or the like, or epiphytic, but current and waves may tear them loose from the substratum, so that they come to be in suspension as "pseudoplankton". To what extent reproduction takes place in this pelagic phase has not been closely investigated. OSTENFELD (1918, p. 266) reports, however, that some of these species are able to reproduce in the plankton, at least for a time. The present author has observed division stages in the material from the Waddensea dealt with here, but only as a rarety. The question how far bottom diatoms, normally

leading a quieter existence on the bottom, can assimilate CO_2 in unweakened intensity in the suspended condition, when the medium is often in strong movement, must apparently be answered in a positive sense; in any case assimilation experiments in the laboratory with material of this group demonstrated strong assimilation activity, although the water used for the suspension in the experiments was kept in fairly strong movement (Grøntved, unpublished paper). The similarity between the suspended bottom forms and the eupelagic species is thus essentially so great, that we are justified in certain cases in dealing with the two groups together.

In addition to the genuine plankton forms and bottom diatoms there is a considerable number of species which show a tychopelagic mode of life, that is, they live for the most part at the bottom, but for a short time of the year they lead a pelagic existence, being loosened often in colonies — from the substratum and held floating in the water. In biological regards this group forms a transitional stage between plankton forms and bottom forms; in our shallow water areas it is numerically well represented; the species in question are noted in the Tables and Diagrams of this paper along with the eupelagic diatoms.

2. Distribution and density of the bottom diatoms on the bottom.

The distribution of the suspended bottom diatoms is shown in Fig. 38; it is far from uniform; the great concentration at the stations 5 and 8 is specially evident. The relatively large number of bottom diatoms in the plankton samples from these stations may presumably come from the forms in question building very dense stocks on the surrounding wads and shallow areas, from which they are washed up in large quantities. Such areas, however, cannot be more nearly defined on the available basis and the distribution otherwise of these organisms can just as little be subjected to a more detailled treatment. It is obvious, that this problem can only be dealt with effectively by means of samples taken at the bottom, which is the natural location of these "wad diatoms".

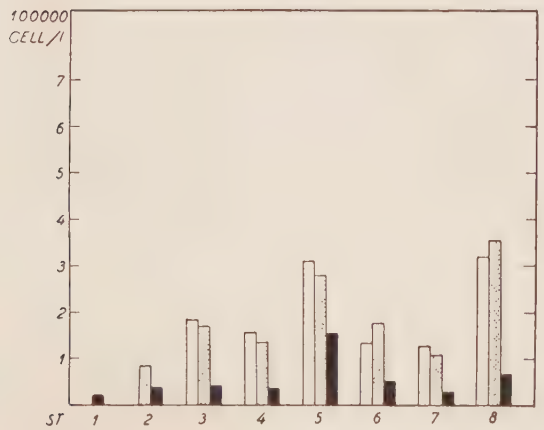

Fig. 38. Average concentration of bottom diatoms in the plankton samples from Sts. 1—8 in July 1941; white — $^{14}/_{7}$, dotted — $^{15}/_{7}$, black — $^{28}/_{7}$.

In the available Waddensea literature we find information regarding some of the factors which are of importance for the distribution of the bottom diatoms in the Waddensea; first, there is the depth of water; Wohlenberg (1931, p. 12) noted, that the optimum distribution area on a wad in the mouth of the Eider lies 5—20 cm. below the line of highwater. In our material the quantitative variation of the bottom diatoms at stations 4 and 5 leads to the conclusion, that the density of the bottom vegetation is greatest in the inner parts of the wad, the number of individuals at these stations distinctly rising with outgoing tide, falling with incoming.

The nature of the bottom, as diatom distributing factor, is shown in the way that the vegetation becomes denser with increasing mud content (Brockmann, 1935 etc.). In connection with this we find that areas with strong currents, where the bottom is often sandy and disturbed, have a relatively small development of diatom stock; under erosion larger or smaller parts

of the vegetation are carried away, and by deposition of sand or other material, which contain only small quantities of diatoms, the individuals present distribute themselves over a larger mass at the bottom; in both cases the result is diminished density of the organisms. Comparing the lists of species from sand wads and mud wads Warming (1904, p. 32) found a different composition of species on these two biotopes.

The salinity of the water, which — apart from areas near freshwater outlets — does not show great fluctuations in the Waddensea, seems to be of no great importance in the distribution of the bottom diatoms, except just in these outlet areas. Brockmann (1935, p. 14) thus finds widespread agreement in the stock of species in the outer Jade, inner Jade and Jade Bay, where the salinity decreases in the order noted of the localities. That the individual density increases inwards is due to the lesser depth of water coupled with weaker current and changed nature of the bottom; the variation of the salinity is without influence on this condition.

In addition to the topographic variation the stock of bottom diatoms shows changes with the time of year, which show themselves on the whole in the flowering in spring and autumn, whilst the individual density is essentially lower during the intermediate periods — especially in winter. Table 23 shows a diatom variation according to the time of year at Sæding wad in Ho Bay; the lower concentration in the winter months is here most obvious when we only take account of living individuals.

As a more occasional cause of changes in the diatom stock we have the water-movements, which in passing storms can reduce the number of individuals greatly, by erosion at such places in the Waddensea where the currents normally permit of a strong development of the stock.

In accordance with the foregoing the number of bottom diatoms per surface-unit is a dimension which varies in dependence on several factors; in the following some information may be given regarding the concentration of these organisms in different and different kinds of — localities. Brockmann (1935, p. 61) in July 1935 undertook a quantitative collection on the wad at Cuxhaven at a spot, where the bottom diatoms formed a brown coating; in one sample, which contained *Pleurosigma angulatum* var. *aestuarii* in so-to-speak pure culture, he found about 500,000 cells per square centimetre of the surface. As Brockmann estimates the average size of the cells of this variety at $75 \times 18\ \mu$, he reckons that the cells have lain in 5 layers in the diatom coating. He notes, that the figures are not always so large as in the sample mentioned, but on the other hand that they can be considerably larger, in the case of small diatom forms. The same author notes further (l. c. pp. 44—45) some diatom frequencies in bottom samples from three localities of a different kind; in the dock mud of Wilhelmshaven he found 438,000 individuals, in mud from the inner Jade 347,000 and in sand from the outer Jade about 19 specimens; the figures are given pr. gr. of the wet bottom samples. Linke (1939, p. 270), who carried out investigations on the wad in Jade Bay, found the number of individuals per cm.^{2} of wad surface to vary from 50,000 to 800,000 and states that the variation in quantity stands in connection with the specific community.

On Sæding wad in Ho Bay the present author has undertaken investigations over a long period with the aim of determining the production of organic matter at this locality; which is a sand-mud wad with a small content of mud. In connection with these investigations the number of bottom diatoms was counted in some of the samples taken for assimilation experiments; this is the group of organisms which is chiefly concerned in the production of stuff in this area; some preliminary results of the enumerations are given in Table 23.

Table 23. Average number of bottom diatoms per cm² of wad bottom at Sæding Strand in Ho Bay; samples taken to a depth of 1 cm.

Date	No. of samples	Living spec.[1])	Empty frustules	Total
VII/1942	5	105,000	45,000	150,000
VIII/1942	3	168,000	110,000	278,000
$^{18}/_{10}$ 42	5	66,000	46,000	112,000
$^{25}/_{11}$ 42	5	50,000	57,000	107,000
$^{21}/_{1}$ 43	4	67,000	95,000	162,000
$^{21}/_{3}$ 43	10	59,000	43,000	102,000
$^{31}/_{2}$ 43	6	187,000	109,000	296,000

The average number of bottom diatoms in the 38 samples examined is 161,000 per cm.² of wad bottom, 94,000 with chromatophores and 67,000 empty frustules. As the samples were taken to a depth of 1 cm. these figures represent (unless some quantities of living bottom diatoms are to be found at greater depths than 1 cm., and this does not seem to be the case as a rule) the quantity of bottom diatoms per cm.² at the locality, though it should be mentioned, that the frequencies noted may be regarded as the lowest values, owing to the method used in preparing the slides. Considering the results of enumerations from other localities it seems probable — taking into account the nature of the bottom at the Sæding wad — that the average diatom density on all the wads in the Danish Waddensea will prove to be greater than the average noted from Sæding wad.

3. Comparison between plankton and bottom diatoms.

As already noted, the diatom stock in the Waddensea is composed of two biological groups: plankton diatoms and bottom diatoms. The former consists of pelagic species, the latter of sessile. Transitional forms are found in the tychopelagic species and in the bottom diatoms, which are found in relatively large numbers held in suspension in the water; the "natural" holding place of these suspended bottom diatoms is the bottom of the waddensea, from which they are broken loose by the mechanical action of the water. The division between plankton and bottom forms is thus to a certain extent not clearly marked, yet we are able, using Tables 23 and 24, to make a comparison between the numbers in the surface waters on the one hand and in the bottom on the other; but the plankton density is given as numbers in a litre of water, whereas the number of bottom diatoms is taken as so many per cm.² of wad surface; to obtain a basis for comparison we must recalculate the plankton concentration in terms of this surface unit.

At a depth of 10 m. there is a column of water of 1000 cc., *i. e.* 1 litre, over 1 cm.² of bottom; assuming that the plankton forms are uniformly distributed in the different layers of water the average frequencies given in Tables 23 and 24 can be compared directly; in other cases and other depths we must correct the frequencies in accordance with the depth in order to express the density per cm.² surface.

[1]) ɔ: With chromatophores or remains of chromatophores.

To facilitate a comparison between the stocks of bottom and pelagic diatoms an abstract has been made from the totals given in Table 25; the result is shown in the following.

Table 24. Average frequency per litre of the diatoms in the plankton samples from 14, 15, and 28, July 1941 (for St. 1 only samples from $^{28}/_{7}$; St. 2 only $^{15}/_{7}$ and $^{28}/_{7}$).

St. No.	Depth at lowwater	No. of samples	All diatoms	Plankton diatoms	Bottom diatoms
1	ca. 1 m.	8	129,625	107,500	22,125
2	ca. 14 m.	12	259,251	194,251	65,000
3	14 m.	22	845,135	716,590	128,545
4	$^{1}/_{4}$—$^{1}/_{2}$ m.	23	224,626	117,321	107,305
5	$2^{1}/_{4}$ m.	23	398,564	152,478	246,086
6	$16^{1}/_{2}$ m.	22	384,196	266,264	117,932
7	ca. 3 m.	24	454,736	362,411	92,325
8	$14^{1}/_{2}$ m.	22	667,704	416,522	251,182

As an example we may make a comparison between the stock of bottom diatoms on the Sæding wad in July 1942 and the pelagic diatom stock at St. 1 on $^{28}/_{7}$ 41. The bottom diatoms have a density of 105,000 living specimens per cm.^{2} surface, the pelagic diatoms at St. 1 have a concentration of ca. 13,000 per cm.^{2}, taking the depth at lowwater as basis for the calculation (this includes a smaller, but not determined number of empty frustules). The station richest in diatoms in 1941 was St. 3; here the average density, including all diatoms, was 1,183,189 per cm.^{2} surface; in contrast to this number which only applies to a small area — owing to the comparatively limited stretch of Rømø Dyb — we have 105,000 living individuals per cm.^{2} surface on the Sæding wad.

Whether in Table 24 we should take the suspended bottom diatoms (last column), as belonging to the bottom vegetation or to the pelagic stock is a matter of opinion. The group is recruited essentially from the bottom, but it has undoubtedly great importance for the production up in the water; for this reason we are entitled to consider these specimens as a part of the plankton, as has been done in the above-noted examples.

It may be noted finally, that care has to be taken in comparing Tables 23 and 24; in the first place they represent in part different species, then there are differences in locality and lastly, the collections have not been made in the same year, though in calendar order. The object of this section has been to show that the bottom diatom vegetation, which was not directly included in the general Waddensea investigation of 1941, by quantitative comparison with the plankton is strongly represented on the wads and in the shallower areas of the Waddensea.

4. Importance of the bottom diatoms.

As mentioned earlier, the stock of bottom diatoms is unequally distributed at different places in the Waddensea, both in qualitative and quantitative regards. As the useful effect of these organisms — however, one may regard this — is of essentiial importance only where they

are present in masses, it is in the main restricted to the diatom-rich parts of the wad; to show the importance of this group, in building up mud, observations have been made in such areas[1]).

According to LINKE (1939, p. 270) the bottom diatoms in Jade Bay are specially numerous on *Pygospio* localities, where at places they form coatings on the wad surface; as the single individuals are surrounded by a cover of mucilage, the uppermost bottom-layer becomes thick with mucilage, the diatoms wandering about in this, and the smaller bottom-particles are thus cemented together[2]). A further effect is, that the coarser materials, which roll over the bottom with the tides, become attached to the diatom coating; of more importance, however, is the fact, that a quantity of "sink-stuff" in fine particles, which fall to the bottom where there is no current or in a feeble current, is likewise caught in the diatom coating and later, as the diatoms work themselves upwards, becomes covered by a layer of mucilage, thus sheltered against the erosive action of the water, provided that the current is not too strong. During stormy weather the diatom coat is often damaged more or less and its sheltering power is limited to a corresponding extent.

By constant repetition of these processes an appreciable heightening of the bottom takes place, over this come diatom layers; the content of mud is greater here than would correspond to the hydrographical conditions for deposition. An unbroken diatom coat thus shelters the bottom material, preventing removal, and contributes by retaining sand grains and organic particles to the heightening of the wad and to increases in the mud content in the sediment. To illustrate this biogenous sedimentation we may give here the results of some analyses LINKE (l. c., Table II) has made on material from the wad bottom. One of the samples (sample *a*) was taken to a depth of 3 cm. on a ca. 20 cm. high and ca. 4 m. square mound, which had been formed by biogenous sedimentation under a diatom coating; LINKE emphasizes that these higher parts, "Bodentafeln", had been formed by the activity of the diatoms. Sample *b* was likewise taken to a depth of 3 cm., 1 m. from the "Bodentafel" from which sample *a* had been taken, in a lower part of the wad, where according to LINKE's account there was no diatom coating.

From LINKE's Table II we give below the values for water, chalk and organic stuff in the two samples (*a* and *b*); further, the thickness of the oxidation layer and an expression for the firmness of the bottom; the analyses of the size of the sand grains — smallest in sample *a* — are not included here.

	Sample *a* weight percent	Sample *b* weight percent
Water	39.1	26.1
Lime	5.9	2.8
Organic stuff	2.8	1.9
Oxidation layer	0.5 cm.	9.0 cm.
Firmness of bottom	20.0 cm.	4.0 cm.

[1]) The word "mud" and constructions formed by it, silting, mud-wads etc., cannot be said to be so clearly defined, that we know exactly what the different authors have in mind when the expression is used, though we may have some idea naturally; in these circumstances it seems most rational to characterise the bottom deposits by means of analyses. In the present work the expression "mud" is used in agreement with the definition given by BROCKMANN (1935, p. 4): "Schlick ist die tonige Ablagerung der Gezeitenmeere". With its wide limits this definition may be taken to include what earlier authors have written about the Waddensea under this name; at the same time it characterises mud as a formation peculiar to the area in question.

[2]) From simple experiments in aquaria one can easily convince oneself of the ability of bottom diatoms to bind together the mud and how, when covered by a thin layer of mud, they can manoeuvre in a short time to get above this and then form a continuous coat.

In agreement with these analyses Broçkmann (1935, pp. 47—50) had earlier found, that the water in the bottom and the content of organic stuff increases with the diatom content.

With regard to the formation of mud, which must be considered a different process from deposition of mud, Brockmann (l. c., p. 62) notes that the bottom diatoms compose the most important part in the organic constituents of the mud; further, they contribute indirectly to the formation of mud, as they provide food for the plankton and wad animals.

It is known that diatom valves are found in large quantities in certain sediments, silicious earth for example being composed almost entirely of this material; in other deposits the diatom content is less; in the wad bottom and marshy ground a varying amount of diatom valves has been found at different places.

Diatom valves do not take part in bottom formation to an extent corresponding to the amount of recent vegetation on the wad, as they evidently perish in great numbers before they succeed in forming a permanent deposit. In reality, of the whole mass of diatoms produced only the coarser valves or parts of valves are preserved and the spores in the case of certain species. Brockmann (1914, p. 46) mentions the following species as the most frequent in deposits on the coasts of the North Sea:

Actinoptychus undulatus and *A. splendens*
Actinocyclus Ehrenbergii
Aulacodiscus argus
Coscinodiscus sp. diversae
Biddulphia aurita, B. rhombus and *B. favus*
Melosira sulcata.

With regard to the origin of the deposited valves it is undoubtedly the case, that the great majority come from bottom and tychopelagic species connected with the wad and the shallow coastal zone; the plankton forms are found in such small numbers in the shallow water, that their valves cannot be expected to be numerically strong in the sediments; even if, naturally, some of these organisms get stranded on the bottom, the great majority have thin valves which are soon destroyed.

For the rest, a fairly uniform content of marine diatom valves is characteristic for many of the Waddensea sediments; this is connected with the strong mixing undergone by the bottom material before the final deposition takes place. Where the conditions in special degree favour the thriving of the diatoms and at the same time present opportunities for mud deposition, then we may find sediments locally which are specially rich in diatoms. Thus, Heiberg (1863, p. 20) found in a few samples of marsh clay from the west coasts of Schleswig such a large proportion of diatom valves, that they amounted to almost half the total mass of the samples. This author does not give the exact locality for these samples, nor does he note for what areas they might be considered characteristic. Such a large amount of diatom content may be considered a rarety in the sediments of the Waddensea. According to Ehrenberg's observations (cf. Wegner, 1909, p. 45) diatom valves composed about $^1/_{20}$th of the amount of mud deposits in the Elbe, Jade, Ems and Schelde; this proportion may be considered to lie nearer the general occurrence in the Waddensea sediments most rich in diatom valves.

Even if the diatom valves do not form a specially large part of the wad sediments, their presence nevertheless may be considered to have a certain importance for the physical nature of the bottom, a condition of interest on considering the possibility of reclaiming land and the

later agricultural exploitation of the areas reclaimed. In an older work (Wegner, 1909, p. 46) it is remarked, that a quantity of diatom valves in sand increases the absorption power, owing to the increased volume of pores. According to the investigations of I. P. Jacobsen & O. Paulsen (1912, pp. 5—6) pores formed about $^{9}/_{10}$ths of the total volume of a plankton sediment; this sediment consisted essentially of plankton diatoms. Brockmann (1935, p. 48) found that a plankton sediment, mainly consisting of the diatoms *Biddulphia sinensis* and *Lithodesmium undulatum*, shrunk from 150 ccm. to 13 ccm. when dried. In natural sediments, where the diatoms compose a smaller part of the mass, the water content is also smaller, though we might expect that diatom sediment consisting of empty frustules would have greater absorption powers than one composed of cells filled with protoplasm.

It has been mentioned earlier (p. 38), that the present author has made a laboratory investigation on the CO_2 assimilation in materials from the uppermost layers of the wad bottom. With the light intensities used during the experiments a strong intensity of assimilation was found; the assimilating organisms were chiefly the bottom diatoms. Although the assimilation values found do not apply directly to the wad locality, being results of laboratory experiments, yet they permit of the conclusion, that the bottom diatoms must be ascribed a no small importance as producers of organic stuff on the wads.

Even though the current conditions in the Waddensea may locally be of such a kind that mud-containing materials can be deposited in considerable quantities without biotic factors contributing to any essential degree, yet there is no doubt, that such factors may be of importance at other places for the accumulation of mud, thus exercising a bottom-forming activity; and they must be a condition for the formation of mud which has a relatively large content of organic stuffs.

Biogenous sedimentation and mud formation are, however, each compounded of many various processes, the details of which lie outside the scope of the present investigations; on the other hand, the preceding pages have given information on some more important investigations and observations which have been made with regard to the occurrence of the bottom diatoms in the Waddensea and the importance they have at places for the protection and growth of the wads, for the composition of the sediments and for the organic stuff production. The group of organisms in question are closely connected systematically with the plankton diatoms, which have been the real object of the investigation, and are richly represented numerically in the plankton samples. Hence the more detailled account of the bottom diatoms whilst omitting other plant organisms (certain phanerogams, green brown and blue-green algae), which also further the sedimentation and contribute to the formation of mud.

It appears from the foregoing, that the bottom diatoms have in general their strongest concentration on the higher lying parts of the wads; thus under natural conditions they exercise their bottom-forming activities mainly in the areas, which first come into consideration in preparation for the reclaiming of land. These attempts aim usually to weaken the currents so as to promote the sedimentation of the smaller and smallest particles suspended in the water and may consist according to the conditions in the construction of breakwaters or mud-fields ("Slikgårde") or the making of trenches[1]) ("Gröbling"). Since weak movements of the water and

[1]) These trenches are dug out periodically, to permit further accumulations of mud.

mud-containing bottom are factors of great importance for the thriving of the bottom diatoms, the attempts referred to tend to increase the stock of these organisms in the area and exploit their bottom-forming activity for the end desired.

VII. Comprehensive summary.

The present work deals with the phytoplankton in the part of the Danish Waddensea which lies south of the tidal area of Graadyb (Fig. 1). It is based on sampling material collected in the second half of July 1941 (Chap. II) and is part of a more extensive scientific investigation set on foot by "Vadehavsudvalget af 1941", which had as object *inter alia* the investigation of possibilities of artificial land reclamation in the area mentioned.

The plankton in the area is greatly dominated — both in number of species and individuals — by the diatoms; this group of organisms has therefore been the chief theme of this paper.

In Chaps. III—V the diatom flora is described from plankton samples taken at the surface at the stations 1—8, E, B, 3b and 5a (Fig. 2). The daily variation in the total numbers of diatoms in agreement with the tides is shown in Figs. 3—27; for the commonest species the quantitative variation is displayed in Tables 1—21. The genuine plankton forms, of which the most frequent are *Asterionella japonica* and *Rhizosolenia Shrubsolei*, have their greatest density in the outermost part of the Waddensea; the species which in mode of life are more or less closely connected with the bottom, either as tychopelagic or purely bottom forms, have their greatest density within the outermost zone of the Waddensea or in the innermost parts, where they can maintain their stock in spite of the strong mixing of the waters in and just outside the Waddensea during the tidal movements. By cross-sections also the Waddensea may be divided into areas with a somewhat diverse floristic character; these biologically separated sections in the case of the plankton forms are the same as the tidal areas; the bottom diatoms have greatest concentration in the plankton samples from the stations B, 5a and 8 (Fig. 2) and may therefore be assumed to form specially dense stocks in the Knudedyb area, but also in Rømø Leje which forms the boundary between the two southern tidal areas. — Although the period of investigation only covers 15 days, variations with a definite tendency in the average number of individuals have been noted in the case of some species; this is most distinct in *Asterionella japonica*, which greatly decreased in frequency during the period mentioned whilst *Rhizosolenia Shrubsolei* showed an increasing maximum; for the rest, the occurrence of the commonest forms is referred to in more detail in Chap. IV and illustrated by Fig. 27—36; these figures show the average frequencies for the 14, 15, and 28, July.

As indicated, the distribution of the diatoms in the Waddensea stands in connection with the water depths, various zones being dominated by their own biological group, and is in the main independent of the variations occurring in the salinity of the water.

Chap. VI gives first a review of the biologically principal groups of diatoms and then discusses the distribution of the bottom diatoms in the "natural" medium on the basis of the occurrence in the plankton samples (Fig. 38), the concentration on the basis of direct observations on Sæding wad in 1942—43 (Table 23); both conditions are further illustrated by reference to the available literature, from which it appears, that the factors of greatest positive importance for the distribution of this group of organisms are weak movements of the water, shallow depth and mud-containing bottom. Then a numerical comparison of sessile and

suspended diatoms was made; it showed that the bottom forms constitute in quantitative regards a considerable part of the total diatom stock in the Waddensea. The last point referred to in Chap. VI deals with the importance of the bottom diatoms in the wad area; with literary sources as basis a description is given of the biogenous sedimentation produced by these organisms; further, their influence on the composition of the sediments and their importance for the production of organic stuff.

If the question be asked, finally, whether the diatoms can have any importance in the matter of possible land reclamation in the area investigated, the bottom diatoms come especially into consideration; they belong naturally to the wads and the shallow areas where such work would be undertaken, and they will find good living conditions at places where the building of breakwaters and mud fields ("Slikgårde") or constructions of trenches ("Gröbling") diminish the strength of the water movements and thus promote the sedimentation of mud particles; under such conditions their bottom-forming activities could be exploited for the end in view.

VIII. Dansk oversigt.

Nærværende arbejde omhandler phytoplanktonet i den del af det danske vadehav, der ligger syd for Graadyb tidevandsområde (fig. 1), det er baseret på et prøvemateriale indsamlet i sidste halvdel af juli 1941 og fremtræder som et led i en mere omfattende videnskabelig undersøgelse, iværksat af "Vadehavsudvalget af 1941", der bl. a. havde til opgave at undersøge muligheder for kunstig landvinding i det pågældende område.

Planktonet i undersøgelsesområdet domineres stærkt, såvel med hensyn til arts- som individantal af diatomeer; denne organismegruppe er derfor afhandlingens egentlige emne.

I kap. III—V beskrives diatomeefloraen på grundlag af planktonprøver udtaget i overfladen på stationerne 1—8, E, B, 3b og 5a (fig. 2). Den daglige variation i totalsummerne af diatomeer i overensstemmelse med tidevandsbevægelserne fremgår af fig. 3—27; for de almindeligste arters vedkommende belyses mængdevariationen af tabellerne 1—21. De genuine planktonter, hvoraf de hyppigste er *Asterionella japonica* og *Rhizosolenia Shrubsolei*, har stærkest koncentration i den yderste del af vadehavet; de arter, der i levevis er mere eller mindre nøje knyttet til bunden enten som tychopelagiske eller rent littorale former, har størst tæthed inden for den yderste zone af vadehavet eller i de inderste partier, hvor de kan hævde sig som bestand trods den kraftige opblanding af vandmasserne i og nærmest uden for vadehavet, der finder sted under tidevandsbevægelserne. Også ved tværlinier kan vadehavet deles i områder med noget forskelligt floristisk præg; disse biologiske afsnit falder for planktonternes vedkommende sammen med de tre tidevandsområder inden for hovedløbene: Knudedyb, Juvre Dyb og Lister Dyb; bunddiatomeerne har stærkest koncentration i planktonprøverne fra stationerne B, 5a og 8 (fig. 2), de må derfor formodes at danne særlig tætte bestande i Knudedyb-området, men også på Rømø Leje, der danner grænsen mellem de to sydlige tidevandsområder. — Skønt undersøgelsesperioden kun omfatter 15 dage konstateredes for nogle arters vedkommende svingninger med bestemt tendens i de gennemsnitlige individantal; tydeligst er dette udtalt hos *Asterionella japonica*, der i den pågældende periode aftog stærkt i hyppighed; *Rhizosolenia Shrubsolei* befandt sig derimod i et tiltagende maksimum; i øvrigt er de almindeligste planktonters forekomst omtalt nærmere i kap. IV og illustreret ved fig. 28—36, på disse figurer er de gennemsnitlige frekvenser d. 14., 15. og 28. juli afbildet.

Diatomeernes fordeling i vadehavet er i det væsentlige uafhængig af de forekommende, små variationer i vandets saltholdighed, vanddybden og forhold, der står i forbindelse hermed, spiller en større rolle, forskellig dybdezoner domineres, som nævnt, hver af sin biologiske gruppe.

I kap. VI gives først en oversigt over diatomeernes biologiske hovedgrupper, dernæst omtales bunddiatomeernes fordeling i det "naturlige" medium på grundlag af forekomsten i planktonprøverne (fig. 38), koncentrationen på grundlag af direkte undersøgelser på Sæding vade i 1942—43 (tabel 23), begge forhold belyses yderligere gennem den foreliggende litteratur,

hvoraf det fremgår, at de faktorer, der har størst betydning for fordelingen af denne organismegruppe er svag vandbevægelse, ringe vanddybde og slikholdig bund. Der er derefter foretaget en talmæssig sammenligning mellem sessile og suspenderede diatomeer, hvoraf ses, at bunddiatomeerne i kvantitativ henseende danner en anselig del af den samlede diatomeebestand i vadehavet. Sidste punkt i kap. VI omhandler bunddiatomeernes betydning i vadeområdet; med litterære kilder som grundlag omtales her den biogene sedimentation, disse organismer formidler, endvidere deres indflydelse på sedimenternes sammensætning og deres betydning for den organiske stofproduktion.

Stilles sluttelig det spørgsmål, om diatomeerne kan få nogen betydning for eventuelle landvindingsarbejder i undersøgelsesområdet, så kommer navnlig bunddiatomeerne i betragtning; de hører naturligt til på vaderne og de lavvandede partier, hvor sådanne indgreb foretages, og de vil få gode levevilkår på steder, hvor man ved bygning af dæmninger og slikgårde eller ved anlæg af grøblingssystemer svækker vandbevægelserne og derved fremmer sedimentationen af slampartikler; under sådanne forhold vil deres bunddannende virksomhed kunne udnyttes til det tilsigtede formål.

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Remarks on Table 25.

At the head of the Table reference is made to figures and tables giving further information regarding hydrographical conditions and the quantitative variation of the plankton at the various stations during the tidal periods mentioned.

The frequency numbers in the Table are calculated as average values for the number of specimens per litre in all samples from the single stations on each of the days of collection; the number of samples is given at the head of the Table.

A + indicates that the species referred to was found by examination of filtered samples (see p. 7); it may be said, that this kind of sample was only taken at the stations 2—6 on the 14, 15, and 28, July, further that finds in these samples are only noted in Table 25 where it is a question of organisms not observed in the quantitative examination of the corresponding water samples.

The *Ciliata* are given as an appendix to the Table; apart from this group the zooplankton has not been included in the present investigation.

Table 25. Average numbers (cells per litre) of organisms in the water samples from the statio

Station No.	1	2		3			4	
Date	28/7	15/7	28/7	14/7	15/7	28/7	14/7	15/7
Number of samples	8	7	5	7	7	8	8	7
Details in fig.	3	4	5	6	7	8	9	10
Details in table	1	2	3	4	5	6	7	8
Diatomeae.								
1. Actinoptychus undulatus	..	..	..	..		..	+	
2. Asterionella japonica	17,250	111,143	27,400	1017,285	632,857	69,375	99,500	70,57
3. Aulacodiscus argus	..			+				
4. Auliscus sculptus	..	..	..	285	429	..	300	..
5. Biddulphia aurita	1,500	2,200	1,200	5,086	7,000	3,125	2,500	1,42
6. — granulata	..			..	..	..		..
7. — regia	375	86	..		286	125	..	..
8. — rhombus	3,625	2,886	2,000	13,057	15,143	6,000	6,250	3,14
9. — sinensis	..	111			+	—	150	..
10. — sp.	..	486	..	571	714	250	2,000	2,28
11. Campylosira cymbelliformis	1,125	572	3,200	5,571	5,143	4,250	..	57
12. Cerataulina Bergoni	..	143	..	..	286	..	..	..
13. Cerataulus Smithii	..		..	285	..	..	..	..
14. — turgidus	250		..	+	+		250	57
15. Chaetoceros affinis	..	..	..	..	..	..	..	..
16. — compressus	..	..	..	..	..	..	..	..
17. — constrictus	..	..	..		..	..	..	..
18. — debilis	1,250	..	..	..	..	3,250	..	..
19. — decipiens	..	..	..	..	..	..	..	..
20. — densus	375	572		285	143			..
21. — sp.	2,000	1,000	3,000	3,129	286	2,750	500	28
22. Coscinodiscus centralis	..	..	..	..	..	..	..	..
23. — concinnus	..	..	..	..	..	..		..
24. — excentricus	..		..	..	..	..	..	..
25. — oculus-iridis	..							..
26. — radiatus	..	429	..	+	..	..	..	..
27. — sp.	..	..			286	+	..	..
28. Eucampia zoodiacus	..	..	..	..	..	..	..	..
29. Grammatophora marina	..	..	..	143	143	..	..	28
30. Guinardia flaccida	2,500		6,400			6,375		..
31. Hyalodiscus scoticus	..	..	..		..	..		..
32. Leptocylindrus danicus	375	..	..	..	429	..	..	..
33. Lithodesmium undulatum	..	5,857	1,000	2,857	1,000	125	3,750	2,28
34. Melosira italica	..	572	..	..	..	125	50	..
35. — sulcata	3,375	2,514	4,200	2,714	2,714	2,375	3,000	1,14
36. — sp.	..	..	..	..	286	..	..	..
37. Nitzschia closterium	1,625	2,129	1,800	22,029	15,857	4,250	11,750	8,28
38. Podosira stelliger	..	..	..	686	..	125	..	..
39. Rhizosolenia fragilissima	..	..	..	571	..	..	..	..
40. — Shrubsolei	60,375	8,000	106,400	3,514	4,571	48,500	550	2,00
41. Sceletonema costatum	10,625	40,571	9,600	114,571	121,000	48,750	53,750	54,00
42. Streptotheca thamensis	625	143	200	..	7,714	..	+	
43. Thalassionema nitzschioides	..	1,143	..	4,571	..	875	..	..

; $^{14}/_{7}$, $^{15}/_{7}$ and $^{28}/_{7}$, 1941. (+ indicates occurrence only in the filtered samples).

	5			6			7			8			
7	$^{14}/_{7}$	$^{15}/_{7}$	$^{28}/_{7}$	$^{14}/_{7}$	$^{15}/_{7}$	$^{28}/_{7}$	$^{14}/_{7}$	$^{15}/_{7}$	$^{28}/_{7}$	$^{14}/_{7}$	$^{15}/_{7}$	$^{28}/_{7}$	
3	8	6	9	8	6	8	8	9	7	8	7	7	
	12	13	14	15	16	17	18	19	20	21	22	23	
)	10	11	12	13	14	15	16	17	18	19	20	21	
	25	222	250	..	..	..	188	..	..	..	..	..	1
25	143,250	47,000	15,222	224,625	185,000	43,500	554,450	228,667	27,571	397,250	405,000	10,286	2
	25	+	+	+	667	125	..	..	..	..	..	..	3
25	750	67	+	+	667	..	..	44	..	..	..	..	4
25	5,625	3,933	1,222	2,000	4,167	875	2,663	1,256	143	1,750	2,143	..	5
	+	+	+	+	..	..	..	..	..	..	..	..	6
	..	..	..	500	..	125	375	556	286	..	286	..	7
25	8,475	17,067	5,333	7,375	4,000	1,125	5,113	4,756	1,571	3,000	1,857	2,571	8
	+	+	+	+	333	+	1,050	111	..	..	..	571	9
	3,700	3,800	333	2,000	2,167	125	2,250	944	571	375	..	..	10
	3,250	2,667	1,889	12,750	15,833	6,500	6,875	2,500	1,857	8,250	9,286	3,286	11
	..	..	..	500	167	..	..	..	..	5,750	4,714	..	12
	250	..	..	..	333	125	313	330	..	..	..	..	13
	50	..	+	+	..	..	..	..	..	..	..	..	14
	..	..	..	..	..	..	..	..	..	2,500	..	..	15
	..	..	..	..	..	..	..	..	..	..	..	857	16
	..	..	..	..	..	..	..	..	..	1,000	..	..	17
	..	..	..	..	..	..	..	..	..	5,500	1,429	27,143	18
	..	..	..	..	..	..	..	..	..	750	..	2,000	19
	+	..	+	250	..	3,500	..	..	..	250	..	..	20
	500	..	222	1,000	333	1,250	..	111	143	3,250	571	4,429	21
	..	..	..	+	..	+	..	..	..	..	..	..	22
	..	..	..	..	..	..	..	..	..	..	..	..	23
	..	..	..	+	..	..	..	..	..	..	..	..	24
	+	..	..	+	..	..	..	..	..	..	..	..	25
	+	..	..	+	..	+	..	..	..	..	..	..	26
25	..	..	..	250	333	..	..	..	..	313	..	..	27
	..	..	..	..	..	500	..	..	..	4,750	857	..	28
	25	67	444	250	..	..	125	..	..	..	..	286	29
75	..	..	222	1,000	500	2,875	..	111	857	5,750	2,571	2,571	30
	..	..	+	+	..	..	..	..	..	..	..	..	31
	..	..	..	..	..	..	..	..	..	..	571	..	32
25	7,600	6,400	4,778	7,750	9,667	2,000	9,763	53,444	2,429	24,500	34,000	857	33
50	500	333	111	..	..	..	..	..	..	..	..	..	34
00	2,150	1,067	667	2,225	7,000	1,000	1,400	1,044	1,429	3,000	1,571	3,714	35
	..	..	..	..	..	..	..	..	..	..	..	..	36
25	49,300	26,867	5,111	24,875	20,167	7,250	20,925	16,822	3,714	28,000	31,286	4,857	37
	..	..	..	..	..	..	..	..	..	..	..	..	38
	..	..	..	500	1,167	..	125	..	..	1,750	..	..	39
25	2,800	3,000	19,444	8,500	7,833	132,625	1,075	2,056	49,714	8,000	10,000	91,571	40
00	39,000	19,000	7,111	18,500	21,500	1,500	30,950	12,444	2,571	33,750	22,429	1,143	41
	..	..	..	..	..	..	375	444	571	3,750	1,571	..	42
	..	..	..	..	..	500	..	..	..	..	..	..	43

(continued)

Table

Station No.	1	2		3			4	
Date	28/7	15/7	28/7	14/7	15/7	28/7	14/7	15/
Number of samples	8	7	5	7	7	8	8	7
Details in fig.	3	4	5	6	7	8	9	10
Details in table	1	2	3	4	5	6	7	8
44. Thalassiosira cfr. decipiens	..	..	..	+	+	..	..	..
45. Triceratium alternans	250	2,000	1,800	629	4,000	500	1,000	2
46. — favus	..	..	+	+	+	+	..	..
47. — sp.	..	..	..	285	286	..	..	..
48. Bottom diatoms, not classified	22,125	83,429	39,200	183,143	170,571	44,000	158,500	136,2
49. **All diatoms**	**129,625**	**296,289**	**207,400**	**1381,567**	**994,144**	**245,125**	**343,800**	**283,4**
Dinoflagellatae.								
50. Ceratium furca	..	..	..	..	..	..	..	..
51. — tripos	..	..	200	57	..	..	..	..
52. Dinophysis acuminata	..	..	..	..	..	..	..	..
53. Gymnodinium sp.	..	1,143	200	..	286	..	500	2
54. Peridinium sp.	..	..	..	..	..	..	500	..
55. Prorocentrum micans	..	..	..	..	143	125	..	..
Chlorophyceae.								
56. Pediastrum Boryanum (Col.)	..	286	..	..	143	..	..	..
57. Scenodesmus quadricauda	500	..	..	..	..	..	..	..
Cyanophyceae.								
58. Merismopedia sp. (Col.)	..	1,171	..	857	..	..	4,500	4
Ciliatae.								
59. Helicostomella subulata	250	1,229	..	2,143	2,000	125	500	5
60. Tintinnopsis beroidea	125	2,286	1,000	2,286	1,857	125	3,500	2,2
61. — campanula	..	..	..	..	..	..	..	..
62. — tubulosa	..	..	..	..	..	..	..	2
63. — sp.	750	286	600	857	..	1,625	1,250	1,4
64. Laboea conica	125	286	200	571	..	500	750	8
65. — constricta	..	..	..	..	..	..	..	..
66. — emergens	..	..	..	..	..	..	..	..
67. — vestita	1,125	8,714	..	686	2,571	1,000	3,100	1,7
68. — sp.	..	971	600	343	714	375	350	..
69. Lohmanniella oviformis	1.500	2,143	200	2,000	1,429	1,750	5,750	2,2

tinued),

	5			6			7			8			
	$^{14}/_{7}$	$^{15}/_{7}$	$^{28}/_{7}$	$^{14}/_{7}$	$^{15}/_{7}$	$^{28}/_{7}$	$^{14}/_{7}$	$^{15}/_{7}$	$^{28}/_{7}$	$^{14}/_{7}$	$^{15}/_{7}$	$^{28}/_{7}$	
	8	6	9	8	6	8	8	9	7	8	7	7	
	12	13	14	15	16	17	18	19	20	21	22	23	
	10	11	12	13	14	15	16	17	18	19	20	21	
	..	..	..	..	..	..	..	..	..	..	..	..	44
25	500	1,333	667	+	..	250	313	388	..	..	857	571	45
	+	+	+	..	..	..	..	..	..	..	..	..	46
	..	..	..	..	..	..	..	..	..	..	..	..	47
50	321,750	281,667	155,111	137,563	178,667	52,750	129,125	108,533	29,429	323,750	354,571	64,857	48
00	**589,525**	**414,490**	**218,137**	**452,413**	**460,501**	**258,500**	**767,453**	**434,561**	**122,856**	**866,938**	**885,570**	**221,570**	49
	..	..	..	..	..	..	..	..	..	..	..	286	50
	..	..	..	..	..	..	..	..	..	..	..	286	51
	..	..	..	..	..	..	..	..	..	..	..	143	52
	500	..	333	750	2,067	250	125	111	..	1,250	571	..	53
	25	333	222	1,625	867	..	350	..	..	250	286	..	54
25	..	..	..	..	..	125	..	..	..	..	..	..	55
	250	..	..	..	200	..	..	..	..	..	..	143	56
	..	..	..	..	..	..	..	..	..	..	..	..	57
25	250	733	222	250	67	1,500	625	388	143	..	286	286	58
	925	333	..	1,875	2,067	125	250	556	286	2,500	3,000	429	59
50	5,875	2,733	..	2,250	2,167	1,125	250	278	143	1,313	571	143	60
	..	..	..	..	..	..	125	..	..	250	..	..	61
	..	..	111	..	..	..	..	..	..	..	..	..	62
00	250	..	778	1,250	1,333	375	..	..	..	..	..	..	63
25	1,000	333	1,000	375	..	1,000	875	1,056	429	750	1,143	1,571	64
	..	..	..	..	333	..	..	..	..	..	..	..	65
	..	..	..	..	..	125	..	..	..	..	..	..	66
	1,500	..	1,778	1,125	3,500	1,375	1,563	700	1,714	313	1,429	3,000	67
75	1,000	67	444	250	1,233	750	800	1,022	1,429	500	1,143	4,000	68
	750	..	111	500	6,000	1,875	125	..	143	3,000	2,000	2,714	69

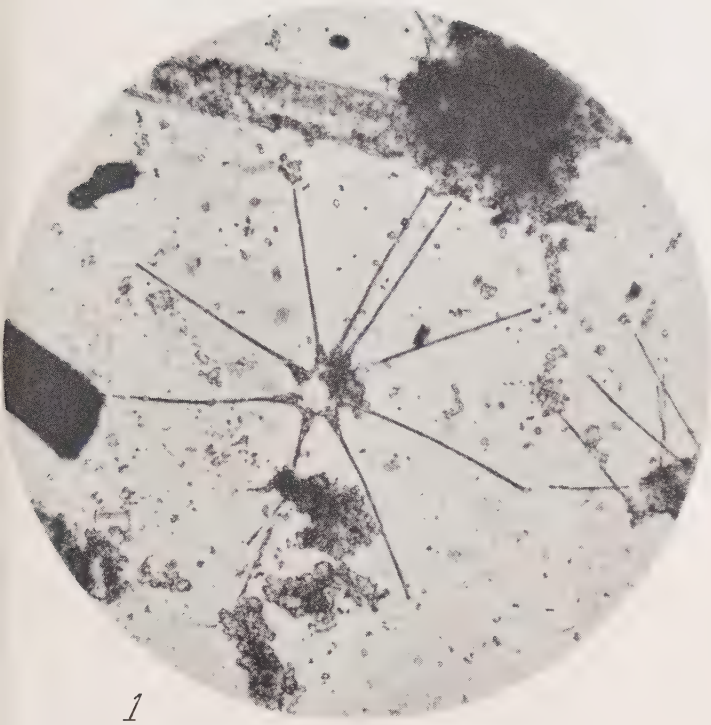
Plate I.

Fig. 1. *Asterionella japonica* Cl. — St. 3, $^{14}/_{7}$ 41. (×360).

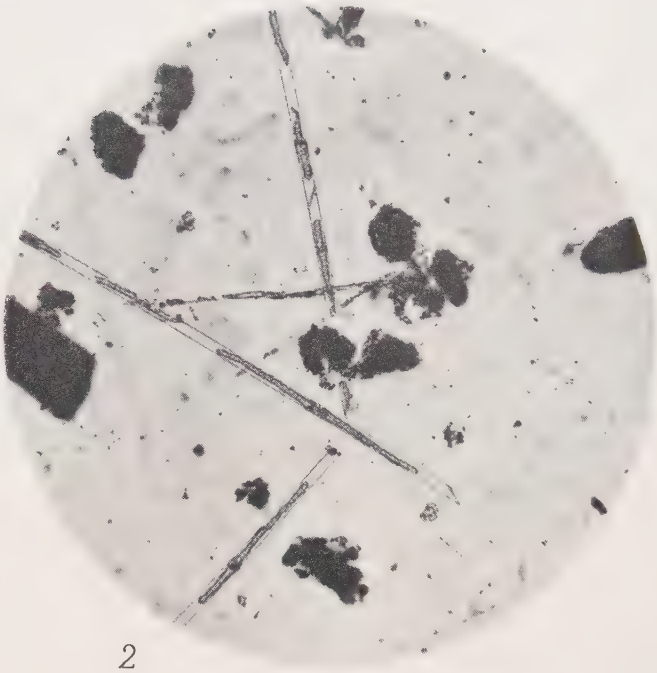
Fig. 2. *Rhizosolenia imbricata* Brightw. var. *Shrubsolei* (Cl.) Schröd. — St. 6, $^{15}/_{7}$ 41. (×84).

Fig. 3. *Biddulphia sinensis* Grev. (The oval bodies of various dimensions seen in the outer part of the picture are animal excrements; such occur with great frequency in the filtered samples everywhere in the Waddensea). — St. 6, $^{15}/_{7}$ 41. (×80).

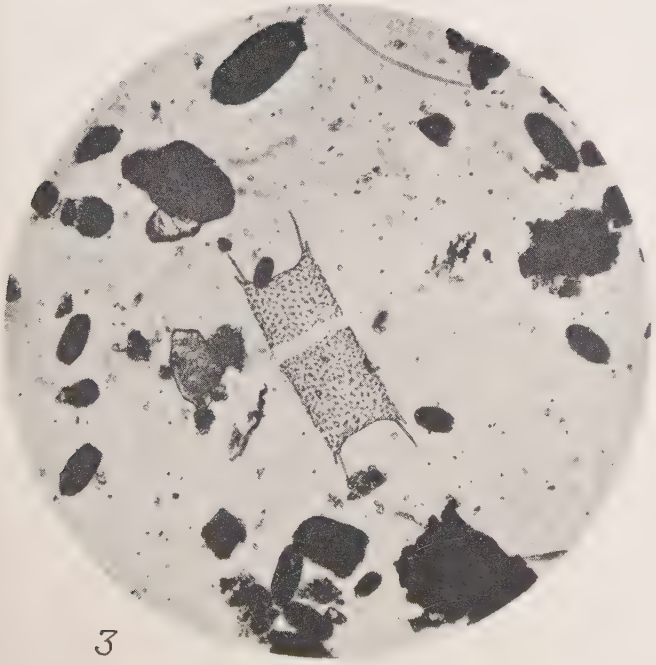
Fig. 4. *Guinardia flaccida* (Castr.) Perag. — St. 6, $^{15}/_{7}$ 41. (×310).



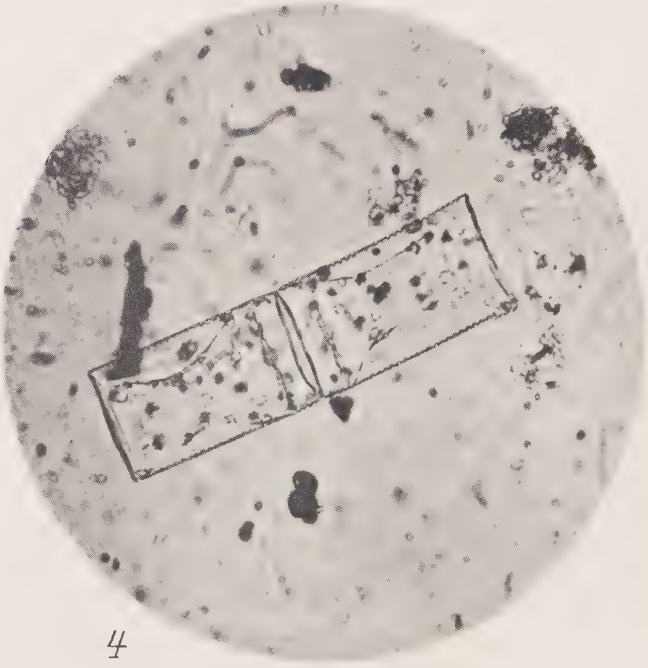
1



2



3

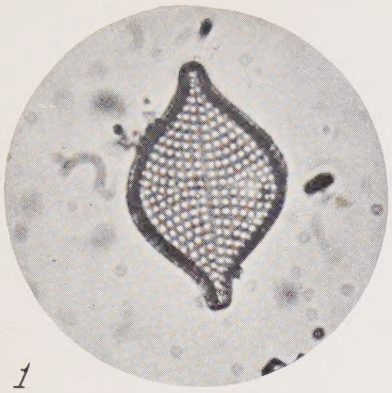


4

Plate II.

The figures on Plate II show diatoms belonging to the biological group bottom diatoms, which in the paper is dealt with only quantitatively.

Fig. 1. *Rhaphoneis amphiceros* Ehr. — St. 8, $^{15}/_{7}$ 41. (×840).
Fig. 2. *Rhaphoneis surirella* (Ehr.) Grun. — St. 3, $^{28}/_{7}$ 41. (×840).
Fig. 3. *Cocconeis scutellum* Ehr. — St. 3b, $^{20}/_{7}$ 41. (×840).
Fig. 4. *Navicula abrupta* Greg. — St. 3, $^{15}/_{7}$ 41. (×840).
Fig. 5. *Surirella striatula* Turp. — St. 6, $^{28}/_{7}$ 41. (×390).
Fig. 6. *Surirella gemma* Ehr. — St. 7, $^{28}/_{7}$ 41. (×730).
Fig. 7. *Pleurosigma aestuarii* Sm. — St. 7, $^{15}/_{7}$ 41 (×750).



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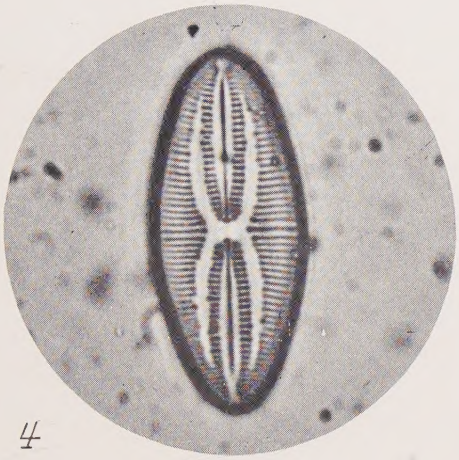

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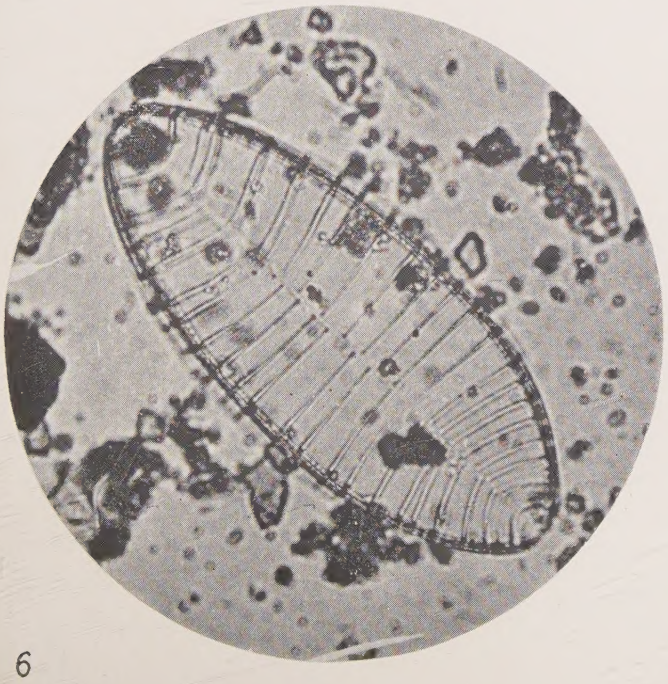

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